



**INTERNATIONAL CRITICAL TABLES**  
**OF**  
**NUMERICAL DATA**  
**PHYSICS, CHEMISTRY AND TECHNOLOGY**  

---

**VOLUME V**





# INTERNATIONAL CRITICAL TABLES OF NUMERICAL DATA, PHYSICS, CHEMISTRY AND TECHNOLOGY

Prepared under the Auspices of the International  
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OF THE  
UNITED STATES OF AMERICA

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VOLUME V

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## Key Numbers of Elements

Ag 82	Al 55	As 13	Au 23	B 54	Ba 79	Be 75	Bi 15	Br 5	C 18	Ca 77	Cb 51	Cd 29	Ce 59	Cl 4	Co 44	Cr 46	Cs 85	Cu 31	Dy 67	Er 69	Eu 64	F 3	Fe 43	Ga 25	Gd 65	Ge 20	Gh 75	H 2	Hf 73	Hg 30	Ho 68	I 6	In 26	Ir 26	K 83	La 58	Li 81	Lu 73		
Mg 76	Mn 42	Mo 47	N 11	Na 82	Nb 51	Nd 61	Ni 45	O 1	Os 35	P 12	Pb 23	Pd 41	Pr 60	Pt 37	Ra 80	Rb 84	Rh 40	Ru 39	S 8	Sa 63	Sb 14	Se 56	Se 9	Si 18	Sn 22	Sr 78	Ta 53	Tb 66	Te 10	Th 24	Ti 19	Tl 27	Tm 70	U 49	V 50	W 48	Y 57	Yb 71	Zn 28	Zr 21





# ERRATA

## VOLUME I

### PAGE

- 52 Thermometric Scales, Steam point. For 703.58°R' read 671.58°R'.
- 68  $\text{NH}_4\text{Cl}$ . For 79.2, 79.3, 79.5 % humidity read 79.5, 79.3, 77.5, respectively.
- 91 High Vacuum Technique, line 5. Insert *m* before = 43.74.
- 176 Index No. 46. Under Normal melting point, °C. For -5 read +2.
- 185 Index No. 544. For  $\text{C}_4\text{H}_2\text{ClN}_2\text{O}_3$  read  $\text{C}_4\text{H}_2\text{Cl}_2\text{N}_2\text{O}_3$ .
- 193 Index No. 1084. For  $\text{CH}_3(\text{C}_3\text{H}_7)\text{CH}_2\text{OH}$  read  $\text{CH}_3(\text{C}_3\text{H}_7)\text{-CHOH}$ .
- 195 Index No. 1158. For  $\text{C}_6\text{H}_5\text{Br}_3$  read  $\text{C}_6\text{H}_3\text{Br}_3$ .
- 200 Index No. 1504. For  $\text{C}_6\text{H}_8\text{O}_5$  read  $\text{C}_6\text{H}_8\text{O}_6$ ; for Mol. wt. 160.06 read 176.06.

### PAGE

- 201 Index No. 1560. For B.P. 196.0 read 166.0.
- 212 Index No. 2260.2. For Isohydroxydimethylurea read Isohydroxydimethyluric acid.
- 213 Index No. 2315. For  $\text{CH}_3\text{BrCONHCON}(\text{C}_2\text{H}_5)_2$  read  $(\text{C}_2\text{H}_5)_2\text{CBrCONHCONH}_2$ .
- 226 Index No. 3066. For Phenylpyrazolone read Phenylpyrazole.
- 235 Index No. 3638. Delete entry.
- 251 Index No. 4612. Delete entry.
- 278 Serial No. 930. Delete entry.
- 390 PREFERENTIAL MOTION. First equation. In exponent of *e* for first  $z^2$  read  $x^2$ .

# ERRATA

## VOLUME II

### PAGE

- 299 For (2) Dellinger and Preston 31, read 32; and for (3) Dellinger and Preston, 32 read 31.
- 328 Table for viscosity of  $\text{CaCl}_2$ , second column. For *a* read  $(\log \eta_w)$ ; for *b* read *a*; and for *c* read *b*.

### PAGE

- 381 Index No. 1017. In last line interchange 450 and 575.
- 462 In footnote \*, for  $\alpha = \alpha_l$  read  $\alpha = \alpha_i$ .

# ERRATA

## VOLUME III

### PAGE

- 211 For Braunschweig, 1909 read 1919.
- 212 At 33.9°C for 39.6772 read 39.677; and at 34.9°C for 41.94 read 41.942.
- 212 For section of Table from 50 to 80°C inclusive, insert head:
- |   |   |   |        |   |
|---|---|---|--------|---|
| 0 | 1 | 2 | etc. → | 9 |
|---|---|---|--------|---|
- 272 AQUEOUS SOLUTIONS OF ORGANIC COMPOUNDS.  $\text{C} = \text{C}_2\text{H}_5\text{O}$ . In table heads for  $\alpha_{20}$  read  $10^2\alpha_{20}$ .

### PAGE

- 273 AQUEOUS SOLUTIONS OF ORGANIC COMPOUNDS.  $\text{C} = \text{C}_2\text{H}_5\text{O}$ . For  $\alpha_{20}$  read  $10^2\alpha_{20}$ .
- 310  $\text{B} = \text{C}_2\text{H}_5\text{O}$ .—(Continued). In Vap. column under 760 mm. for 40.8 read 41; for 59.8 read 60; for 80 read 81; and delete all other decimal places.

# ERRATA

## VOLUME IV

### PAGE

- 183  $\text{C}_6\text{H}_{12}\text{O}$ , Cyclohexanol. For 3.828 read 38.28.
- 253 SUBSTITUTED PHENOLS IN WATER AT 25°C. Add (37) and add soln. after Equiv. per l.
- ALKALOIDS IN WATER AT 20°C. Add (80); cf. (4).
- ORGANIC ACIDS IN WATER AT 25°C. Add (37) and add soln. after Equiv. per l.
- 281  $\text{Cl}^- \text{SO}_4^- \text{Mg}^{++} \text{Na}^+$ .—(Continued). Under *t* = 105°C, insert asterisks after H and I; in line for P, for 14.78 read 14.76; in line for Q, for 67.28 read 54.96, for 54.04 read 64.82, and for 20.24 read 20.54.

### PAGE

- 309  $\text{Cl}^- \text{Mg}^{++}$  (252):  $\text{H}_2\text{O} + \text{MgO} + \text{MgCl}_2$ . Add *t* = 50°C.
- 351  $\text{SO}_4^- \text{Mg}^{++} \text{Na}^+$ . At 103°C, in first entry, for 42.9m read 28.05m and for 10.31m read 6.73m; in second entry, for  $\text{Na}_2\text{SO}_4$  read  $3\text{Na}_2\text{SO}_4 \cdot \text{MgSO}_4$ , for 27.92 read 18.24, and for 25.4 read 16.57.
- 394 For (257) Mayeda, 41 read (257) Maeda, 142.
- 459 In  $\text{C}_6\text{H}_{17}\text{BrO}_2$ , act.-Amyl  $\alpha$ -bromo-*n*-butyrate, delete question mark.
- 475 To (13) add Goard, 4, 127: 2451; 25.





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Aqueous solutions, containing: Only salts or strong inorganic electrolytes.	Solutions aqueuses, contenant: Seulement des sels ou des électrolytes inorganiques forts.	Wässrige Lösungen, enthaltend: Nur Salze oder starke anorganische Elektrolyte.	Soluzioni acquose, contenenti: Solo sali oppure elettroliti inorganici forti.	12
At least one weak electrolyte or organic acid or base.	Au moins un électrolyte faible ou un acide ou une base organique.	Mindestens einen schwachen Elektrolyten oder eine organische Säure oder Base.	Almeno un elettrolita debole oppure un acido organico o una base..	20
At least one non-electrolyte but no weak electrolyte.	Au moins un non-électrolyte mais aucun électrolyte faible.	Mindestens einen Nichtelektrolyten aber keinen schwachen Elektrolyten.	Almeno una sostanza non elettrolita e nessun elettrolita debole.	21
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## VISCOSITY OF GASES

L. L. BIRCUMSHAW AND VAUGHAN H. STOTT

### DEFINITIONS AND FORMULAE

For small velocities, the rate of shear in a gas is proportional to the shearing stress. The ratio of the latter to the former is known as the viscosity ( $\eta$ ). The C. G. S. unit of viscosity is called the "poise."

In the case of most gases, the influence of temperature on the viscosity may be represented by the following formula due to Sutherland (1893):

$$\eta = \eta_0 \frac{T_0 + C}{T + C} \left( \frac{T}{T_0} \right)^{3/2}$$

where  $\eta$  and  $\eta_0$  are the viscosities at the absolute temperatures  $T$  and  $T_0$ , respectively, and  $C$  is "Sutherland's constant."  $C$  may readily be determined graphically from a number of observations by plotting  $T$  against  $T^{3/2}/\eta$ , since we have

$$T = \left[ \frac{T^{3/2}}{\eta} \right] \left[ \frac{\eta_0 (1 + \frac{C}{T_0})}{T_0^{3/2}} \right] - C$$

### FLOW OF GAS THROUGH A CAPILLARY TUBE

For very small velocities, the following equation due to Meyer may be used:

$$F = \frac{\pi r^4}{16\eta l p} \left( 1 + \frac{4\xi}{r} \right) (p_1^2 - p_2^2),$$

where  $F$  = volume of gas (measured at mean pressure  $p$ ) flowing per second,  $p_1$  = entrance pressure,  $p_2$  = exit pressure,  $l$ ,  $r$  = length and radius of the tube, respectively, and  $\xi$ , the slip coefficient, is approximately equal to the mean free path of the molecules.

Except at very small velocities, the above formula requires a considerable correction for kinetic energy. The corrected formula may be written, according to Brillouin (3)

$$p_1^2 - p_2^2 = \frac{p}{\rho} \left[ \frac{16\eta l M}{\pi r^4 \left( 1 + \frac{4\xi}{r} \right)} + \frac{2M^2}{\pi^2 r^4} \right],$$

where  $M$  = the mass of gas transpired per second and  $\rho$  = the density of the gas at the mean pressure  $p$ .



$$RT \log_e \frac{p_1}{p_2} = -\frac{1}{384} \left[ \frac{p_1^2 - p_2^2}{\eta p_1 l} \right]^2 [r^4 + 12\xi^2 r^2 + 6\xi r^3],$$
$$\eta = \eta' \left[ 1 + A \frac{r^4(p_1 - p_2)}{l} \right],$$

## FLOW OF GASES THROUGH TUBES

In most measurements of gaseous viscosities, the value for air at a given temperature is either assumed or determined. Unless otherwise indicated, the viscosity values in the following tables have been corrected, in cases where the air value assumed or determined by the author is known, by assuming that for air  $\eta_{12} = 1822.6 \times 10^{-7}$  (<sup>9</sup>) and that  $C = 120$ .

### A-TABLE.—ELEMENTARY SUBSTANCES AND ATMOSPHERIC AIR

Gas	t, °C	$\eta$ , micro-poise ( $10^{-8}$ poise)	Remarks	Lit.
A	0 23	209.6 221.0	C = 142	(20, 21, 22) (10)
Br <sub>2</sub>	12.8 65.7 99.7 139.7 179.7 220.3	151 170 188 208 227 248	C = 460	(24)
Cl <sub>2</sub>	12.7 99.1	129 168	C = 325	(23)
H <sub>2</sub>	23  0 -192.3 -252.5 -257.7 0 + 20.8 -102.9 -183.5 -202.2 -253.06 -253.06	88.2  84.2 36.2 8.5 5.7 (84.11) 88.72 60.93 39.22 31.93 11.10 10.6	{ C = 72, Breitenbach C = 83, Rayleigh }  Down to -183°; $\eta = \eta_0 \left( \frac{T}{273.1} \right)^{0.695}$ ; p = ca. 400 mm except for last value, where p = 200 mm	(42)  (7)  (15)

Gas	$t, ^\circ\text{C}$	$\eta$ , micro- poise ( $10^{-4}$ poise)	Remarks	Lit.
H <sub>2</sub> , Vap.	B. P. (=	1.0		
H <sub>2</sub> , Liq.	-252.7)	13.00	$d = 0.0708 \text{ g/ml}$	(40)
He	0	187.3	C = 70	(20, 21, 22)
	23	198.1		
	23	196.2 <sub>3</sub>		(5, 10)
	15	108.6		
	0	186.0		
	-191.6	87.1		(7)
	-252.6	35.0		
	-257.4	27.0		
	0	(188.7)		(16)
	+ 21.43	199.4		
	- 22.8	178.8		
	- 70.0	156.4		
	-102.6	139.2		
	-184.3 <sub>5</sub>	91.85	$\eta = \eta_0 \left( \frac{T}{273.1} \right)^{0.647}$	(16)
	-198.0	81.54		
	-252.9 <sub>3</sub>	35.03		
	-258.1	29.46		
Hg	273	494		(11)
	313	551		
	369	641		
	380	654		
I <sub>2</sub>	124.0	184		(25)
	170.0	204		
	205.4	220		
	247.1	240	C = 590	
Kr	0	232.7	C = 188	(20, 21, 22)
N <sub>2</sub>	23	176.5	C = 110.6, Bestelmeyer	(42)
Ne	0	297.3	C = 56	(20, 21, 22)
O <sub>2</sub>	23	203.9	C = 127, Eglin	(35, 42)
Rn	0	212.4 (calc.)	C = 337 (calc.)	(20, 21, 22)
Xe	0	210.1	C = 252	(20, 21, 22)

Atmospheric air based on Harrington's value at 23° (°) and computed with  $C = 120$ ; unit is  $10^{-7}$  poise

°C	$\eta$	Dif.	°C	$\eta$	Dif.
0	1709	50	200	2582	38
10	1759	49	210	2620	38
20	1808	48	220	2658	38
30	1856	48	230	2696	37
40	1904	47	240	2733	37
50	1951	46	250	2770	36
60	1997	46	260	2806	36
70	2043	46	270	2842	35
80	2088	45	280	2877	35
90	2132	44	290	2912	34
100	2175	43	300	2946	34
110	2218	42	310	2980	34
120	2260	42	320	3014	33
130	2302	42	330	3047	33
140	2344	41	340	3080	33
150	2385	40	350	3113	33
160	2425	40	360	3146	33
170	2465	40	370	3179	33
180	2505	39	380	3212	33
190	2544	38	390	3245	32



Atmospheric air.—(Continued)

°C	$\eta$	Dif.	°C	$\eta$	Dif.
400	3277	32	460	3463	30
410	3309	31	470	3493	30
420	3340	31	480	3523	30
430	3371	31	490	3553	30
440	3402	31	500	3583	
450	3433	30			

No change in the viscosity of air could be detected in an electric field of 18 000 volt/cm (30). For effect of saturation with vapors, *v. p. 6.*

B-TABLE.—STANDARD ARRANGEMENT

(v. Vol. III, p. viii)

Substance	$t, ^\circ\text{C}$	$\eta$ , micro- poise ( $10^{-6}$ poise)	C	Lit.
H <sub>2</sub> O.....	v. Table 1			
HCl.....	12.5 100.3	138.5 182.2	357	(8)
HBr.....	18.7 100.2	181.9 234.4		
HI.....	20.6 100.2	185.7 238.3	390	(8)
SO <sub>2</sub> .....	0 18 100	117 124.2 161.6	416	(33, 41)
H <sub>2</sub> S.....	0 17 100	116.6 124.1 158.7	331	(26)
NO.....	0	178		(41)
N <sub>2</sub> O.....	0	135		(41)
NH <sub>3</sub> .....	- 78.5 0 100	67.2 91.8 129.3	370	(26, 41)
PH <sub>3</sub> .....	0 15 100	106.1 112.0 143.8	290	(26)
AsH <sub>3</sub> .....	0 15 100	145.8 114.0 198.1	300	(26)
CO.....	-191.5 - 78.5 0 15 100	56.1 127 166 172 210	118	(31, 41)
CO <sub>2</sub> .....	v. Table 2			
CS <sub>2</sub> .....	0 14.2	91.1 96.4		(36)
COS.....	15 100	119.0 154.1	330	(33)
C <sub>2</sub> N <sub>2</sub> .....	0 17 100	92.8 98.7 127.1	330	(26)
SiH <sub>4</sub> .....	15 100	112.4 142.4	229	(27)

C-TABLE.—THE C-ARRANGEMENT (v. Vol. III, p. viii)

Formula	Name	$t, ^\circ\text{C}$	$\eta$ , micro- poise ( $10^{-6}$ poise)	C	Lit.
CHCl <sub>3</sub>	Chloroform.....	0 14.2 100 212.5	93.6 98.9 129 164	292	(29, 36, 41)
CH <sub>3</sub> Br	Methyl bromide.....	0	103		
CH <sub>3</sub> Cl	Methyl chloride.....	- 15.3 15.0 99.1 182.4 302.0 0	92 104 137 168 211 96.9		
CH <sub>4</sub>	Methane.....	-181.6 - 78.5 0 0 17 100	34.8 76.0 102.4 102.7 108.5 135.2		
C <sub>2</sub> H <sub>2</sub>	Acetylene.....	0	93.5		(41)
C <sub>2</sub> H <sub>4</sub>	Ethylene.....	15.0 99.3 182.4 302.0	99 126 151 180	226	(1)
C <sub>2</sub> H <sub>5</sub> Cl	Ethyl chloride.....	0	93.7		
C <sub>2</sub> H <sub>6</sub>	Ethane.....	- 78.5 0	63.4 84.8		
C <sub>2</sub> H <sub>5</sub> O	Ethyl alcohol.....	100 212.5	108 140		
C <sub>3</sub> H <sub>6</sub> O	Acetone.....	100 212.5	93.1 124	670	(29)
C <sub>3</sub> H <sub>5</sub> O <sub>2</sub>	Ethyl formate.....	99.8	92		(18)
C <sub>3</sub> H <sub>7</sub> O <sub>2</sub>	Methyl acetate.....	99.8 100 212.5	98 100 134	660	(18, 29)
C <sub>3</sub> H <sub>7</sub> Br	<i>n</i> -Propyl bromide....	99.8	119		(18)
C <sub>3</sub> H <sub>7</sub> Br	Isopropyl bromide....	99.8	122		(18)
C <sub>3</sub> H <sub>7</sub> O	<i>n</i> -Propyl alcohol.....	99.9	93		(18)
C <sub>3</sub> H <sub>7</sub> O	Isopropyl alcohol.....	99.8	109		(18)
C <sub>4</sub> H <sub>8</sub> O <sub>2</sub>	Propyl formate.....	99.9	92		(18)
C <sub>4</sub> H <sub>8</sub> O <sub>2</sub>	Ethyl acetate.....	0 99.8 100 212.5	68.4 96 94.3 126	650	(29); cf. (18, 41)
C <sub>4</sub> H <sub>8</sub> O <sub>2</sub>	Methyl propionate....	99.8	94		
C <sub>4</sub> H <sub>10</sub>	<i>n</i> -Butane (1% C <sub>2</sub> H <sub>6</sub> )..	14.7 16.0 100	83.2 83.3 108.2		
C <sub>4</sub> H <sub>10</sub>	Isobutane.....	23	75.5		(10)
C <sub>4</sub> H <sub>10</sub> O	Ethyl ether.....	0 14.2 99.8 100 212.5	67.8 71.6 98 95.5 122	325	(18, 29, 36, 41)
C <sub>4</sub> H <sub>10</sub> O	Trimethyl carbinol....	99.8	102		



C-TABLE.—The C-ARRANGEMENT.—(Continued)

Formula	Name	$t, ^\circ\text{C}$	$\eta$ , micro- poise ( $10^{-6}$ poise)	C	Lit.
$\text{C}_4\text{H}_{11}\text{N}$	<i>n</i> -Butylamine .....	99.8	82		(18)
$\text{C}_4\text{H}_{11}\text{N}$	Isobutylamine .....	99.8	88		(18)
$\text{C}_4\text{H}_{11}\text{N}$	Diethylamine .....	99.9	92		(18)
$\text{C}_5\text{H}_{10}\text{O}_2$	Isobutyl formate .....	99.8	93		(18)
$\text{C}_5\text{H}_{10}\text{O}_2$	Ethyl propionate .....	99.9	88		(18)
$\text{C}_5\text{H}_{12}$	Isopentane .....	100 212.5	87.4 115	500	(29)
$\text{C}_6\text{H}_6$	Benzene .....	14.2 100 212.5	73.8 91.8 123	700	(29, 36)

TABLE 1.— $\text{H}_2\text{O}$  VAPOR (34) $\eta$  in  $10^{-6}$  poise

$^\circ\text{C}$ .....	100.0	151.2	207.1	261.3	C
$\eta$ .....	127	145	168	190	650
$^\circ\text{C}$ .....	0	15	20.6	28.9	99.95
$\eta$ (obs.) .....	90.4	97.5	97.5	100.6	132.0
$\eta$ (extrap.)* .....	88	93	96	100	127

\* Taking C = 650.

TABLE 2.— $\text{CO}_2$  $\eta$  in  $10^{-6}$  poise (39, 41)

$^\circ\text{C}$	23	0	-78.5
$\eta$	147.15	137	102
C	274*	240†	

\* Rankine and Smith.

† Breitenbach.

The following table for  $\text{CO}_2$  is given by Phillips (17). $\eta$  in  $10^{-6}$  poise;  $d$  in  $\text{g}/\text{cm}^3$ 

$P$ , atm.	$\eta$	$d$	$\eta/d$
20 $^\circ\text{C}$			
83	823	0.835	986
72	771	0.812	950
59	697	0.768	907
56	186	0.190	977
50	177	0.145	1220
40	166	0.100	1660
20	156	0.036	4330
1	148	0.00183	80800
30 $^\circ\text{C}$			
110.5	770	0.795	968
104	733	0.781	939
96	693	0.760	913
90	643	0.743	864
82	592	0.716	827
80	565	0.706	800
76	529	0.680	778
74	495	0.664	745
73	478	0.653	732
72	458	0.635	723
70	229	0.287	798
60	187	0.177	1057
40	168	0.092	1830
20	159	0.0354	4500
1	153	0.00177	86400

TABLE 2.— $\text{CO}_2$ —(Continued)

$P$ , atm.	$\eta$	$d$	$\eta/d$
32 $^\circ\text{C}$			
120	788	0.790	998
112	741	0.777	954
104	695	0.760	914
93	627	0.729	860
87	586	0.700	837
84	560	0.682	822
80	528	0.655	807
76	448	0.597	751
75	406	0.555	730
74	254	0.360	700
70	214	0.255	840
60	187	0.170	1100
40	175	0.090	1950
20	162	0.0352	4600
1	155	0.00176	88100
35 $^\circ\text{C}$			
114.5	693	0.755	918
109	660	0.741	891
96	586	0.696	841
88	511	0.653	782
85	456	0.626	728
80	361	0.494	731
75	237	0.289	820
70	214	0.227	943
60	178	0.163	1091
40	174	0.085	2045
20	163	0.0348	4680
1	156	0.00174	89600
40 $^\circ\text{C}$			
112	571	0.699	817
108	540	0.682	792
100	483	0.636	761
94	414	0.582	712
85	269	0.385	698
80	218	0.291	748
70	200	0.204	981
60	187	0.153	1220
40	176	0.083	2120
23.8	169	0.0408	4140
1	157	0.00173	90800

## GAS MIXTURES

A-B TABLE.—STANDARD ARRANGEMENT

He -  $\text{H}_2$  $\eta$  in micropoises ( $10^{-6}$  poise) (5)

% He	% $\text{H}_2$	$\eta$		$t, ^\circ\text{C}$	C
		Calc.	Obs.		
100.1 (sic.)	0.0	189.09	189.25	0.00	
		195.46	195.36	13.37	71.4
		234.08	234.10	100.05	
96.094	3.906	184.60	185.00	0.0	
		192.17	191.77	15.93	73.9
		228.95	229.07	100.22	
89.559	10.431	176.00	175.96	0.0	
		182.02	182.14	12.63	89.8
		220.36	220.33	100.02	
86.400	13.600	172.35	173.27	0.0	
		180.10	179.29	16.86	85.7
		215.27	215.57	100.05	



A-B TABLE.—(Continued)

% He	% H <sub>2</sub>	$\eta$		$t, ^\circ\text{C}$	C
		Calc.	Obs.		
75.087	24.913	159.71	160.32	0.0	77.8
		166.35	165.67	15.86	
		198.35	198.47	99.67	
59.716	40.284	142.52	143.06	0.0	87.75
		148.14	147.55	14.67	
		178.23	178.40	99.80	
39.857	60.143	122.24	122.67	0.0	75.50
		127.00	126.53	15.03	
		151.73	151.77	100.09	
18.807	81.193	101.56	101.65	0.0	80.63
		106.09	106.01	17.0	
		126.48	126.50	100.15	
0.0	100.00	84.10		0.0	83.0
		87.40	87.72	14.79	
		104.95	104.60	100.5	

O <sub>2</sub> - H <sub>2</sub>							
11.1°C (6)	% O <sub>2</sub> .....	100	97.5	95	90	75	0
	$\eta_{\text{rel.}}$ .....	1	0.9957	1.000	0.9946	0.9724	0.4502

O <sub>2</sub> - N <sub>2</sub>					
12.2°C (6), $\eta$ (for 100% O <sub>2</sub> ) = 1					
% O <sub>2</sub>	$\eta_{\text{rel.}}$	% O <sub>2</sub>	$\eta_{\text{rel.}}$	% O <sub>2</sub>	$\eta_{\text{rel.}}$
97.5	0.9984	66.6	0.9550	10	0.8847
95	0.9941	50	0.9348	5	0.8804
90	0.9871	33.3	0.9138	2.5	0.8847
75	0.9734	25	0.9051	0	0.8750

O <sub>2</sub> - CO							
$\eta_{\text{O}_2}$ at $t^\circ = 1$ (6)							
12.2°C	% O <sub>2</sub> .....	100	25	10	5	2.5	0
	$\eta_{\text{rel.}}$ .....	1	0.9040	0.8842	0.8757	0.8743	0.8701
11.1°C	% O <sub>2</sub> .....	100	75	66.7	50	33.3	0
	$\eta_{\text{rel.}}$ .....	1	0.9666	0.9593	0.9361	0.9129	0.8664

O <sub>2</sub> - CO <sub>2</sub>								
$\eta_{\text{O}_2}$ at $t^\circ = 1$ (6)								
13.3°C	% O <sub>2</sub> ..	100	50	25	10	5	2.5	0
	$\eta_{\text{rel.}}$ ...	1	0.8714	0.8071	0.7679	0.7559	0.7538	0.7464
12.2°C	% O <sub>2</sub> ..	100	97.5	95	90	75	0	
	$\eta_{\text{rel.}}$ ...	1	0.9943	0.9872	0.9759	0.9420	0.7510	

O <sub>2</sub> - CH <sub>4</sub>								
$\eta_{\text{O}_2}$ at $t^\circ = 1$ (6)								
12.8°C	% O <sub>2</sub> ..	100	50	25	10	5	2.5	0
	$\eta_{\text{rel.}}$ ...	1	0.8076	0.6902	0.5983	0.5827	0.5770	0.5629

H <sub>2</sub> - SO <sub>2</sub> (38)							
17°C		45°C		70°C		92°C	
% H <sub>2</sub>	$\eta \times 10^7$	% H <sub>2</sub>	$\eta \times 10^7$	% H <sub>2</sub>	$\eta \times 10^7$	% H <sub>2</sub>	$\eta \times 10^7$
0.00	1241	0.00	1366	0.00	1476	0.00	1576
17.85	1274	19.72	1404*	19.72	1513	19.72	1609
49.25	1330	49.25	1452	30.01	1534	30.01	1624
70.37	1350	70.37	1472	38.25	1551	38.25	1651
77.14	1324	77.14	1431	51.77	1564	51.77	1657
83.24	1285	83.24	1389	70.37	1573	76.94	1616
100.00	875	100.00	931	76.94	1528	83.43	1554*
				83.43	1483	83.24	1550*
				83.24	1478*	100.00	1022
				100.00	979		

 H<sub>2</sub> - SO<sub>2</sub>—(Continued)

124°C		153°C		199°C	
% H <sub>2</sub>	$\eta \times 10^7$	% H <sub>2</sub>	$\eta \times 10^7$	% H <sub>2</sub>	$\eta \times 10^7$
0.00	1714	0.00	1869	0.00	2041
32.40	1751	32.40	1914	32.40	2087
53.02	1787	53.02	1931	50.95	2090
67.35	1775	67.35	1914	67.35	2068
83.64	1660	83.24	1777	84.88	1924
100.00	1086	84.88	1722	100.00	1219
		100.00	1152		

\* For these values the temperature reading was obtained by interpolation over more than 5°C.

 H<sub>2</sub> - N<sub>2</sub>

12.8°C (6), $\eta_{\text{rel.}}$ to	% H <sub>2</sub> .....	100	50	0
O <sub>2</sub> = 1	$\eta_{\text{rel.}}$ .....	0.04493	0.8014	0.8690

 H<sub>2</sub> - N<sub>2</sub>O

11.1°C (6), $\eta_{\text{rel.}}$ to	% H <sub>2</sub> .....	25	10	0
O <sub>2</sub> = 1	$\eta_{\text{rel.}}$ .....	0.7510	0.7481	0.7481

 H<sub>2</sub> - NO

11.1°C; values of % H<sub>2</sub> and of  $\eta$  relative to O<sub>2</sub> = 1 (6)

100 %	75 %	50 %	25 %	10 %	5 %	0 %
0.4482	0.7159	0.8224	0.8491	0.8609	0.8788	0.8661

 H<sub>2</sub> - NH<sub>3</sub>

12-13°C; values of % H<sub>2</sub> and of  $\eta$  in 10<sup>-7</sup> poise (37)

0.0 %	8.2 %	20.1 %	33.9 %	53.6 %	68.4 %	79.1 %	90.2 %	100.0 %
1005	1017	1042	1068	1102	1104	1089	1036	915

 H<sub>2</sub> - CO

11.1°C;  $\eta_{\text{rel.}}$  to O<sub>2</sub> = 1 (6)

% CO.....	100	95	92.5	90	75	0
$\eta_{\text{rel.}}$ .....	0.8664	0.8650	0.8635	0.8650	0.8432	0.4586

 H<sub>2</sub> - CO<sub>2</sub>

Values of % H<sub>2</sub> and of  $\eta_{\text{rel.}}$  to O<sub>2</sub> = 1 (6)

12.8°	100 %	25 %	10 %				
	0.4493	0.7535	0.7521				
12.2°	100 %	97.5 %	95 %	90 %	75 %	50 %	0 %
	0.4321	0.4983	0.5157	0.5722	0.6786	0.7339	0.7470

$\eta$  in 10<sup>-7</sup> poise

% H <sub>2</sub>	14.7°	% H <sub>2</sub>	14.7°	% H <sub>2</sub>	15°	99.2°	% H <sub>2</sub>	15°
(19)*		(19)*		(1)			(37)	
0.0	1468	90.16	1215	0.0	1464	1869	0.0	1468
9.97	1477	93.58	1111	12.98	1484		8.5	1483
19.85	1491	96.12	1031	15.56		1897	17.2	1490
27.75	1499	97.60	991	14.99		1880	22.4	1493.5
56.54	1475	98.32	958	48.44	1485	1805	55.4	1485
73.59	1399	100	893	82.20	1289	1624	66.7	1450
83.92	1307			97.24	991	1195	76.5	1367
				100	893	1064	82.2	1292
							87.9	1901

\* Not corrected to standard air value.

 H<sub>2</sub> - CH<sub>4</sub>

Values of % H<sub>2</sub> and of  $\eta_{\text{rel.}}$  to O<sub>2</sub> = 1 (6)

12.2°	100 %	17.5 %	10 %	5 %	2.5 %	0 %	
	0.4497	0.5572	0.5629	0.5615	0.5502	0.5544	
12.8°	100 %	97.5 %	95 %	90 %	75 %	50 %	0 %
	0.4616	0.4714	0.4797	0.4965	0.5313	0.5596	0.5481

 H<sub>2</sub> - C<sub>2</sub>H<sub>4</sub>

12-13°;  $\eta$  in 10<sup>-7</sup> poise (37)

% H <sub>2</sub> .....	0.0	27.1	45.6	63.0	72.6	83.0	92.4	100.0
$\eta$ .....	1016	1048	1078	1087	1086	1062	1008	915



NH<sub>3</sub> - C<sub>2</sub>H<sub>4</sub>12-13°;  $\eta$  in 10<sup>-7</sup> poise (37)

% NH <sub>3</sub> .....	0.0	8.0	17.5	27.5	42.0	58.9	81.3	100.0
$\eta$ .....	1016	1037	1043	1047	1050	1046	1028	1005

Air - H<sub>2</sub>

16.1°C (6)

% H <sub>2</sub> .....	100	95	90	75	25	0
$\eta_{rel.}$ (O <sub>2</sub> = 1).....	0.4434	0.5282	0.5880	0.7488	0.8790	
$\eta_{rel.}$ (air = 1).....	0.4927	0.5869	0.6534	0.7987	0.9767	1

16.4°C	% H <sub>2</sub> .....	50	10	5	0
	$\eta_{rel.}$ (O <sub>2</sub> = 1).....	0.8197	0.8888	0.8960	
	$\eta_{rel.}$ (air = 1).....	0.9108	0.9876	0.9956	1

Air - H<sub>2</sub>O

Saturated at 26°; 10<sup>7</sup> $\eta$  = 1904 (air = 1863) (13). Stearns (35.1) claims that the viscosity of air is decreased by saturating it with moisture, the decrease being  $\frac{1}{3}$  % at 760 mm and 35 % at 14 mm pressures.

Air - C<sub>2</sub>H<sub>4</sub> $\eta$  in 10<sup>7</sup> poise; not corrected to standard air value (1)

% C <sub>2</sub> H <sub>4</sub> .....	100	90.3	69.0	54.6	30.0	13.6	0.0
$\eta$ (15°).....	1011	1078	1236	1345	1548	1692	1809
$\eta$ (99.3°).....	1282	1367		1674		2069	2209

Air - C<sub>2</sub>H<sub>5</sub>OHSaturated at 26°; 10<sup>7</sup> $\eta$  = 1878 (air = 1863) (13).

## LITERATURE

(For a key to the periodicals see end of volume)

- (1) Breitenbach, 8, 67: 803; 99. (2) Breitenbach, 8, 5: 166; 01. (3) Brillouin, *Leçons sur la viscosité des liquides et des gaz*. Paris, Gauthier-Villars, 1907. (4) Fisher, 2, 32: 216; 11. (5) Gille, 8, 38: 799; 15. (6) Graham, 62, 126: 573; 46. (7) Günther, 7, 110: 626; 24. (8) Harle, 5, 100: 429; 21. (9) Harrington, 2, 8: 738; 16. (10) Ishida, 2, 21: 550; 23. (11) Koch, 8, 19: 857; 83. (12) Kuenen and Visser, 64V, 22: 336; 13. 168, No. 138a; 13. (13) Millikan, 3, 19: 209; 10. (14) Millikan, 2, 21: 217; 23. (15) Onnes, Dorsman and Weber, 64V, 15: 1375; 13. 168, No. 134a; 13. (16) Onnes and Weber, 64V, 15: 1385; 13. 168, No. 134b; 13. (17) Phillips, 5, 87: 48; 12. (18) Pochettino, 59, 8: 33; 16. (19) Puluj, 428, 15: 598, 633; 79. (20) Rankine, 5, 83: 265, 516; 10. (21) Rankine, 3, 21: 45; 11. (22) Rankine, 5, 84: 181; 11. (23) Rankine, 5, 86: 162; 12. (24) Rankine, 5, 88: 575; 13. (25) Rankine, 5, 91: 201; 15. (26) Rankine and Smith, 3, 42: 615; 21. (27) Rankine and Smith, 67, 34: 181; 22. (28) Rapp, 2, 2: 363; 13. (29) Rappenecker, 7, 72: 695; 10. (30) Ray, 3, 43: 1129; 22. (31) Smith, 67, 34: 155; 22. (32) Smith, 3, 44: 289; 22. (33) Smith, 3, 44: 508; 22. (34) Smith, 5, 106: 83; 24. (35) States, 2, 21: 662; 23. (35.1) Stearns, 2, 27: 116; 26. (36) Suhrmann, 90, 14: 56; 23. (37) Thomsen, 8, 36: 815; 11. (38) Trauts and Weisel, 8, 78: 305; 25. (39) Van Dyke, 2, 21: 250; 23. (40) Verschaffelt, 64P, 20: 986; 18. 168, No. 153b; 18. (41) Vogel, 8, 43: 1235; 14. (42) Yen, 3, 38: 582; 19.

## VISCOSITY OF METALS AND ALLOYS

W. ROSENHAIN, EDITOR

## Definitions and Meanings of Symbols

- $S_e$  Tensile stress.  
 $S_g$  Shearing stress.  
 $e$  Unit elongation.  
 $g$  Shear.  
 $E$  Young's modulus of elasticity.  
 $G$  Modulus of rigidity.  
 $\xi$  "Normal" coefficient of viscosity.  
 $\eta$  Tangential coefficient of viscosity.  
 $\delta$  Logarithmic decrement of damped vibrations.

The coefficients of elasticity and viscosity of an isotropic solid body are defined by the equations:

$$S_e = Ee + \xi \frac{de}{dt}$$

$$S_g = Gg + \eta \frac{dg}{dt}$$

The coefficient of viscosity of a liquid is defined by:

$$S_g = \eta \frac{dg}{dt}$$

The physical significance is different, however, the order of magnitude being 10<sup>-12</sup> that for a solid.

The logarithmic decrement is the logarithm of the ratio of two successive maximum displacements, on the same side of the equilibrium configuration.

NOTE.—For material possessing no symmetry whatever, there are 21 elastic and 36 viscous constants, which are coefficients in the six linear equations giving the six stress components in terms of the six strain components and their time derivatives. The constants in the following tables have been computed on the assumption that the material is isotropic, though this is admittedly not the case in unannealed wires and possibly not in the other materials investigated.

In general, the coefficients of viscosity computed on this basis from the logarithmic decrement of vibrations, increase linearly with the amplitude of vibration. This may be due either to "after-effect" or to the fact that terms quadratic in the strain-

velocities are necessary completely to define the stress components in terms of the strain components. For a discussion of the theory, see (11). The values of the coefficients for an amplitude of  $\theta^\circ$  are designated by  $\xi_\theta$  and  $\eta_\theta$ .

The values of the coefficients of viscosity of solid metals and alloys depend not only upon their chemical composition but very largely on their condition, especially their microstructure. The values given below are to be applied only to material in the same condition and only to specimens whose size is of the same order of magnitude as the specimens for which the results are given.

## VISCOSITY OF SOLID METALS AND ALLOYS

F. P. UPTON

"NORMAL" COEFFICIENT OF VISCOSITY FOR ZERO AMPLITUDE AT ROOM TEMPERATURE, CGS UNITS

Determined from damping of flexural vibrations of rectangular strips

Material	Treatment	Dimensions, cm			Period, sec	10 <sup>-8</sup> $\xi_0$	Lit.*
		l	m	n			
Ag	Hammered.....	26.0	0.500	0.104	0.731	2.85	(5)
	Annealed at 400°C...	26.0	0.500	0.104	0.719	2.24	
	Rolled.....	26.0	0.719	0.0999	0.709	0.75	(5)
Al	Rolled.....	26.0	0.372	0.0997	0.798	0.82	
	Annealed at 400°C...	26.0	0.719	0.0999	0.716	1.25	
	Cast.....	†	†	†	0.684	0.165†	(11)
Cd	Cast.....	†	†	†	0.934	0.257†	
	Cast.....	†	†	†	0.892	8.0†	(11)
	Cast.....	†	†	†	1.220	11.4†	
Cu	Rolled.....	26.0	0.380	0.134	0.586	4.86	(5)
	Rolled.....	26.0	0.380	0.134	0.838	5.11	
	Rolled.....	26.0	0.373	0.049	0.903	4.68	
Cu-Sn-P	Annealed at 300°C...	26.0	0.380	0.134	0.610	5.16	
	Cast.....	†	†	†	0.708	0.29†	(11)
	Cast.....	†	†	†	0.537	0.41†	(11)
Cu-Zn	Cast.....	†	†	†	1.010	0.34†	
	Cast.....	†	†	†	0.732	0.23†	(11)
	Cast.....	†	†	†			
Cu, 60; Zn, 40	Rolled.....	26.0	0.354	0.155	0.535	1.55	(5)
	Unannealed.....				0.750	4.94	(5)
	Annealed.....	26.0	0.489	0.0726	0.756	2.68	
Fe-C, 0.18							



"NORMAL" COEFFICIENT OF VISCOSITY.—(Continued)

Material	Treatment	Dimensions, cm			Period, sec	$10^{-8}\xi$	Lit.
		l	m	n			
Fe-C, 0.38	Unannealed	26.0	0.497	0.0892	0.688	5.12	( <sup>5</sup> )
	Annealed				0.684	3.51	
Fe-C, 0.67	Unannealed	26.0	0.500	0.123	0.479	5.93	( <sup>5</sup> )
	Annealed				0.481	4.30	
Fe-C, 1.17	Unannealed	26.0	0.497	0.0811	0.708	5.06	( <sup>5</sup> )
	Annealed				0.701	4.27	
Fe-C, 1.75	Unannealed	26.0	0.480	0.0725	0.766	7.20	( <sup>5</sup> )
					0.508	1.25**	( <sup>11</sup> )
Fe-C	Cast (steel)	†	†	†	0.724	1.58**	( <sup>11</sup> )
					0.480	3.6††	( <sup>11</sup> )
Fe-C	Cast (iron)	†	†	†	0.641	6.0††	( <sup>11</sup> )
					0.751	1.61	( <sup>11</sup> )
Mg	Hammered	26.0	0.500	0.120	0.755	0.722	
	Annealed at 400°C.				0.550	3.05	( <sup>5</sup> )
Ni	Rolled	26.0	0.497	0.105	0.553	0.96††	( <sup>11</sup> )
	Cast	†	†	†	0.978	27.4	( <sup>5</sup> )
Zn	Rolled	26.0	0.356	0.0669	0.883	9.27	
	Annealed at 200°C.						

\* Results of (<sup>5</sup>) were each obtained from damping of vibrations in *vacuo* of a strip loaded at lower end. Results of (<sup>11</sup>) were each obtained from damping of vibrations of a strip fixed at one end and at the other attached to a heavy disk rotatable in the plane of flexure, the plane of strip when unstrained passing through axis of disk. In (<sup>11</sup>) only values of  $\frac{\xi}{E}$  were given. Values of  $\xi$  are computed from values of  $E$  given below.

In (<sup>5</sup>)  $\delta = \frac{mn^3T}{8MT^2} \xi$ , where  $M$  is mass of load and  $T$  is period ( $\frac{1}{2}\delta$  is called log decrement in the original). In (<sup>11</sup>)  $\delta = \frac{mn^3T}{4M'l^3} \xi$  where  $M'$  is mass of heavy disk.

The results in this table are not corrected for effect of non-rigidity of support.

For methods, v. (<sup>16</sup>). For more recent data, v. (<sup>17</sup>).

† Average dimension of strips,  $10 \times 0.6 \times 0.1$  cm.

‡ Assumed  $E = 6570$  kg/mm<sup>2</sup>.

§ Assumed  $E = 7070$  kg/mm<sup>2</sup>.

|| Assumed  $E = 10800$  kg/mm<sup>2</sup>.

¶ Assumed  $E = 9400$  kg/mm<sup>2</sup>.

\*\* Assumed  $E = 20750$  kg/mm<sup>2</sup>.

†† Assumed  $E = 9000$  kg/mm<sup>2</sup>.

‡‡ Assumed  $E = 20300$  kg/mm<sup>2</sup>.

#### TANGENTIAL COEFFICIENT OF VISCOSITY FOR ZERO AMPLITUDE (<sup>6</sup>)

Determined from damping of torsional vibrations of annealed wires; for effect of temperature, v. Figs. 1-10

Material	$t, ^\circ\text{C}$	Length, cm	Radius, cm	Period, sec	$10^{-8}\eta^*$
Ag	13	25.5	0.0285	9.671	12.50
Al	15	25.5	0.0315	7.035	25.50
Au	15	25.5	0.0280	9.603	17.00
Cu	22	25.7	0.0275	6.899	6.70
Fe	16	25.4	0.0295	5.744	12.89
Fe-C, 0.55	22	25.6	0.0290	5.684	12.90
Fe-C, 0.9	16	23.7	0.0335	5.693	7.70
Fe-C, 1.30	19	25.5	0.0275	6.670	9.82
Ni	16	25.5	0.0250	6.521	1.65
Pt	15	25.6	0.0240	8.198	1.75
Pt, 85; Rh, 15	17	25.5	0.0195	10.059	4.19
W	16	25.5	0.0215	7.625	9.37
Zn	22	25.5	0.0270	8.642	410.7

\*  $\delta = \frac{\pi R^4 T}{4Il} \eta$ , where  $R$  = radius of wire,  $l$  = length of wire,  $T$  = period,  $I$  = moment of inertia of load ( $\frac{1}{2}\delta$  is called log decrement in the original paper, and tabulated values are  $\log_{10}$ );  $\eta$  in poises.

#### VISCOSITY OF LIQUID METALS AND ALLOYS

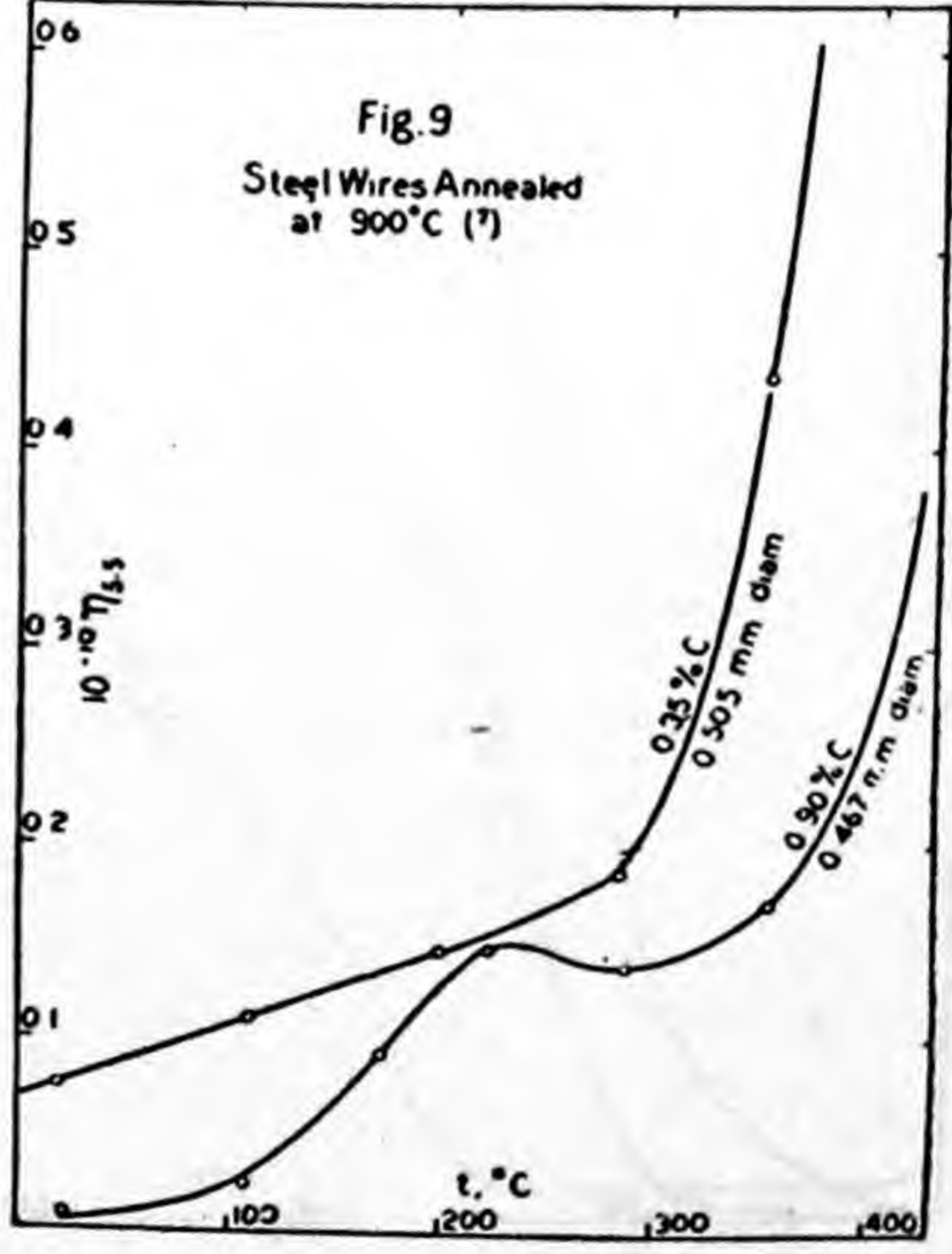
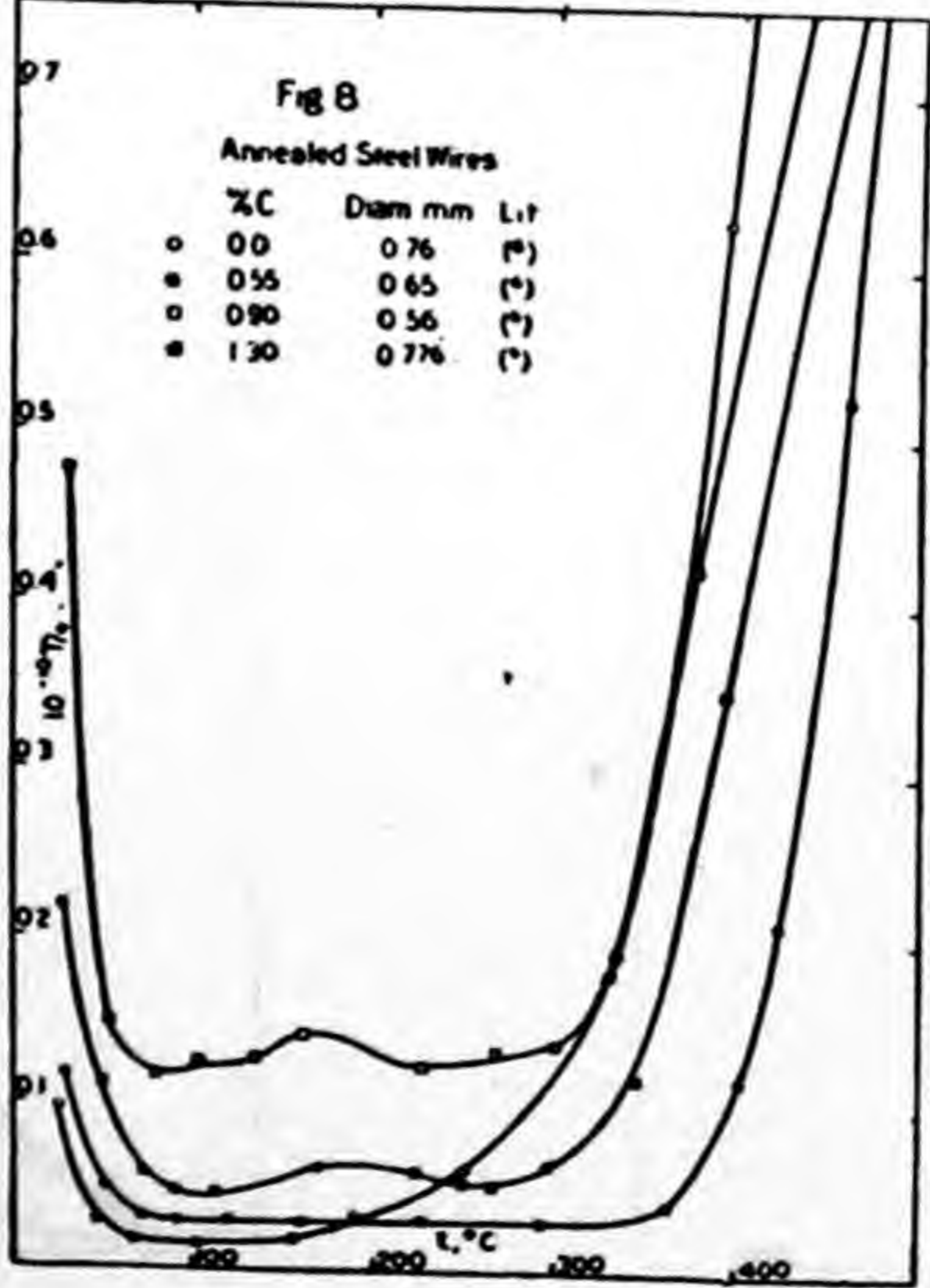
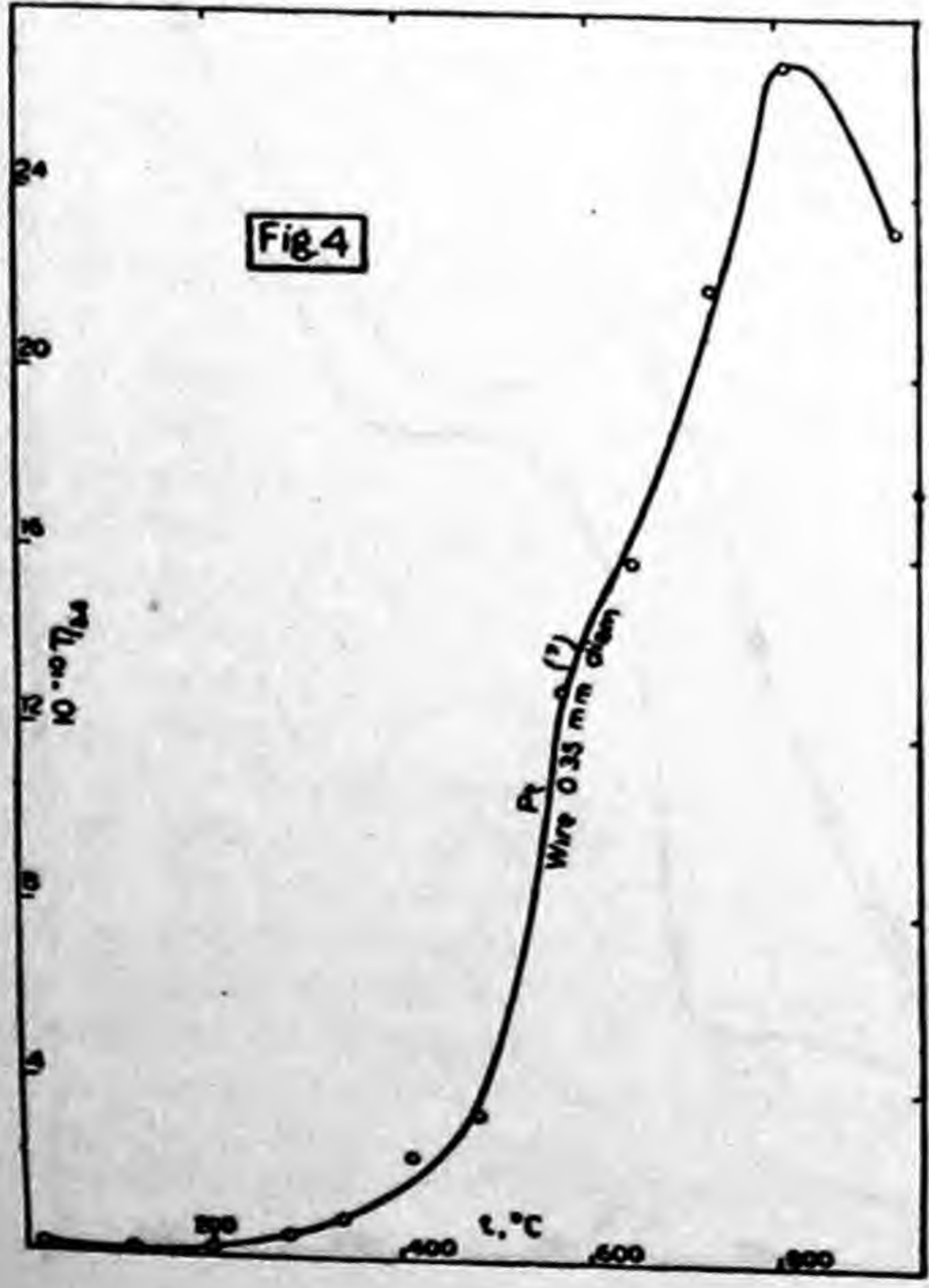
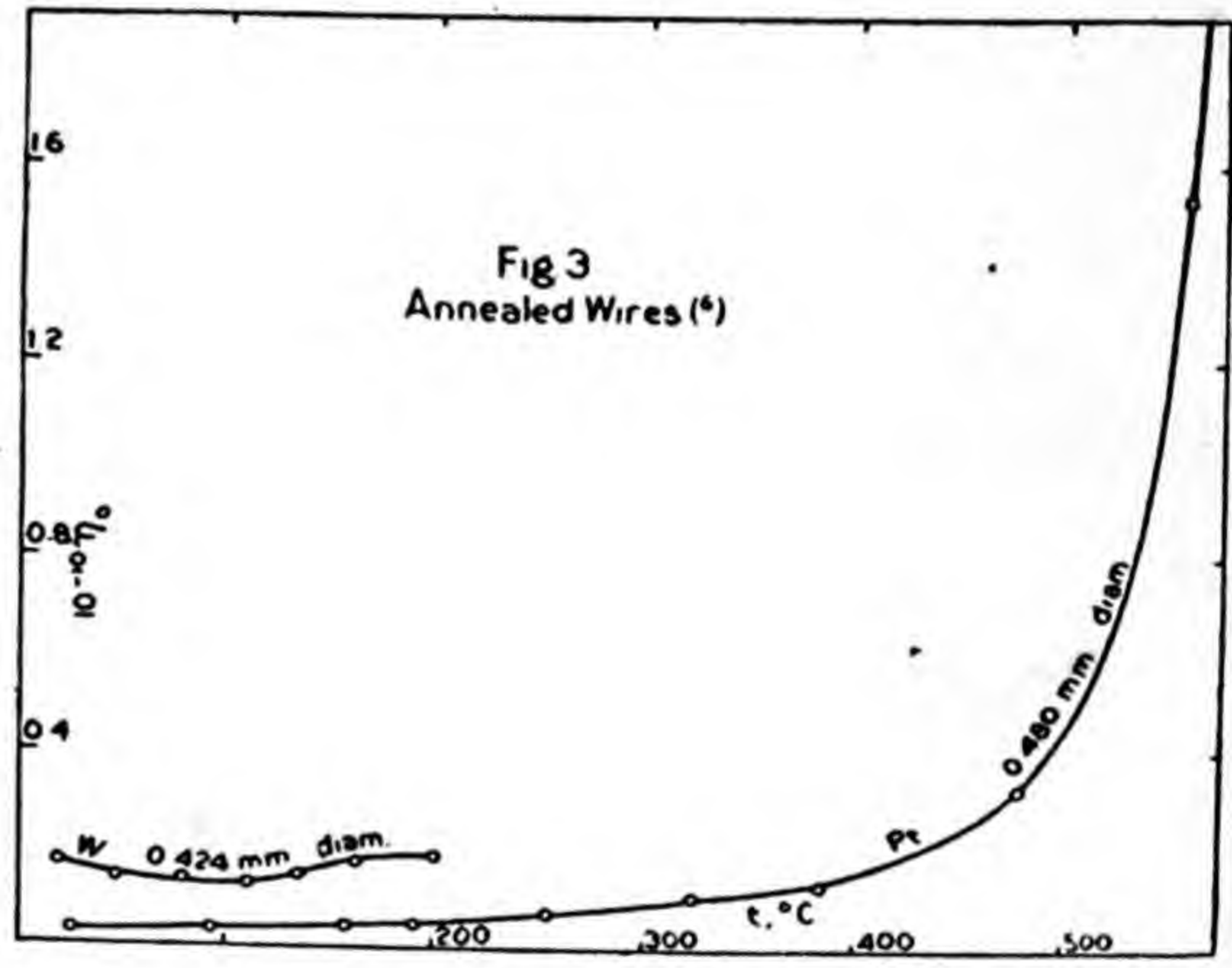
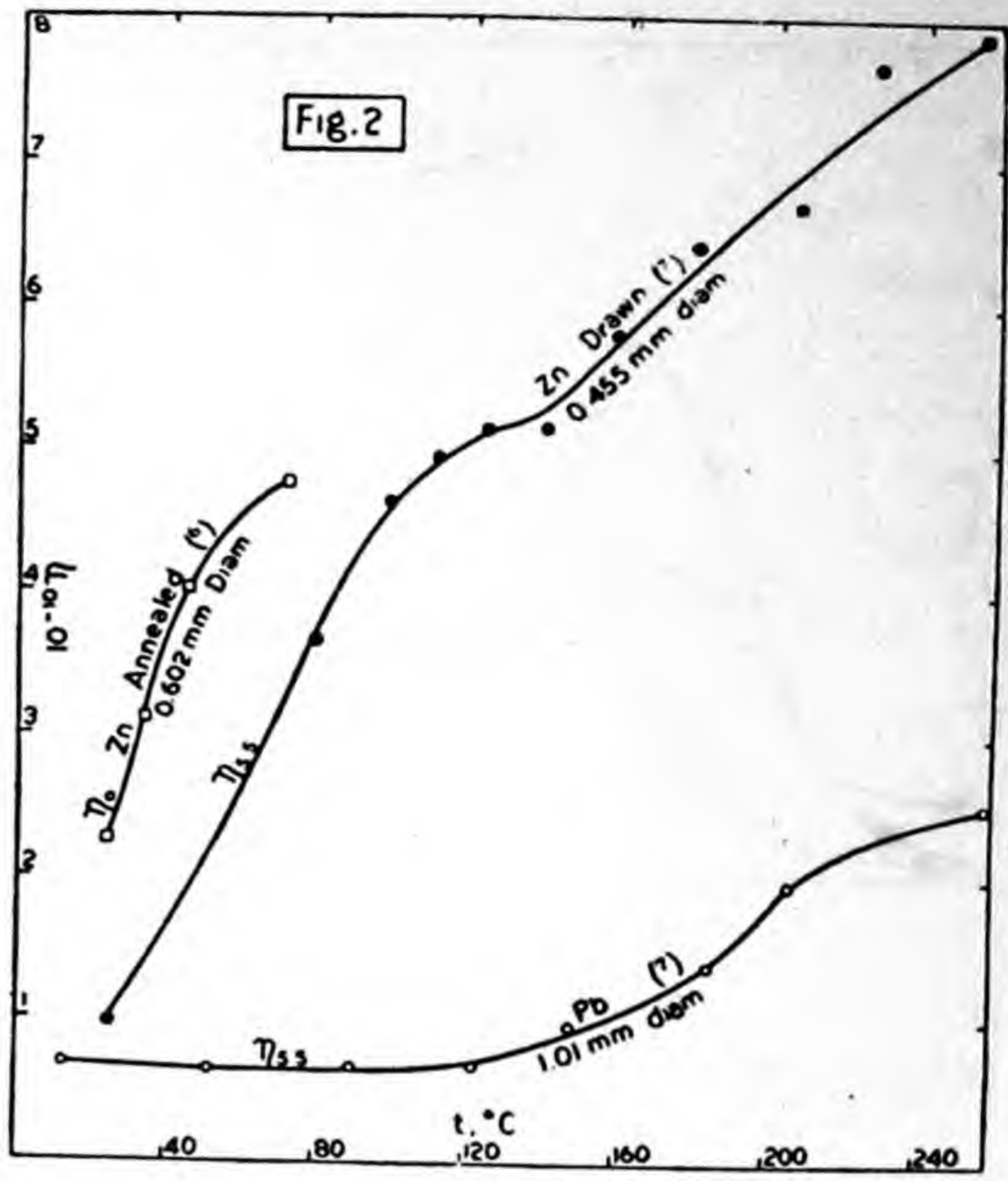
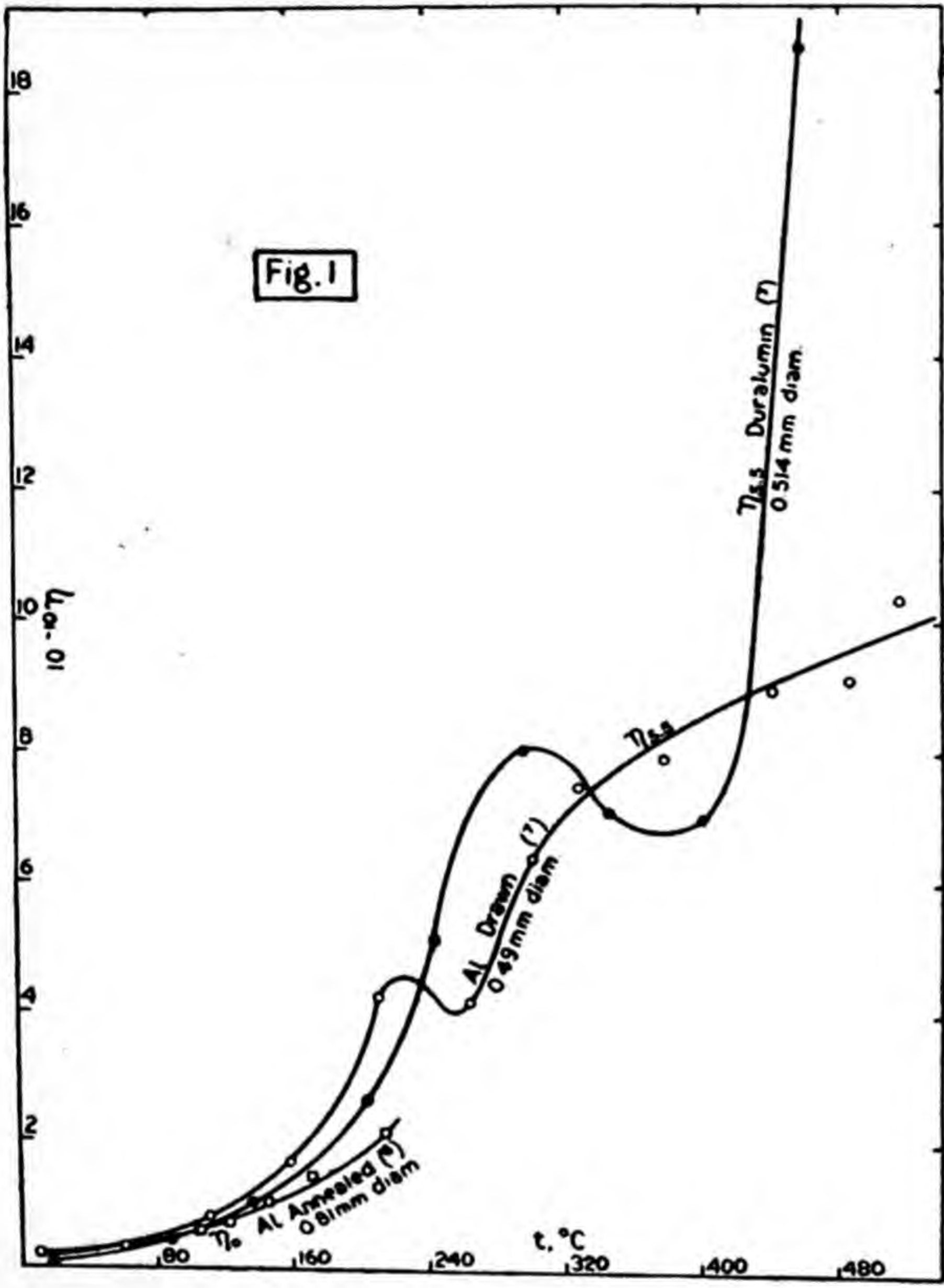
C. H. M. JENKINS (CHMJ), N. E. DORSEY (NED), O. F. HUDSON (OFH), T. K. ROSE (TKR)

% Composition	$t, ^\circ\text{C}$	$100\eta$	% Composition	$t, ^\circ\text{C}$	$100\eta$
Bi, 100 ( <sup>13</sup> )	304	1.662	Bi, 77.88; Sn,	306	1.682
	451	1.280	22.12	444	1.318
	600	0.998		600	1.049

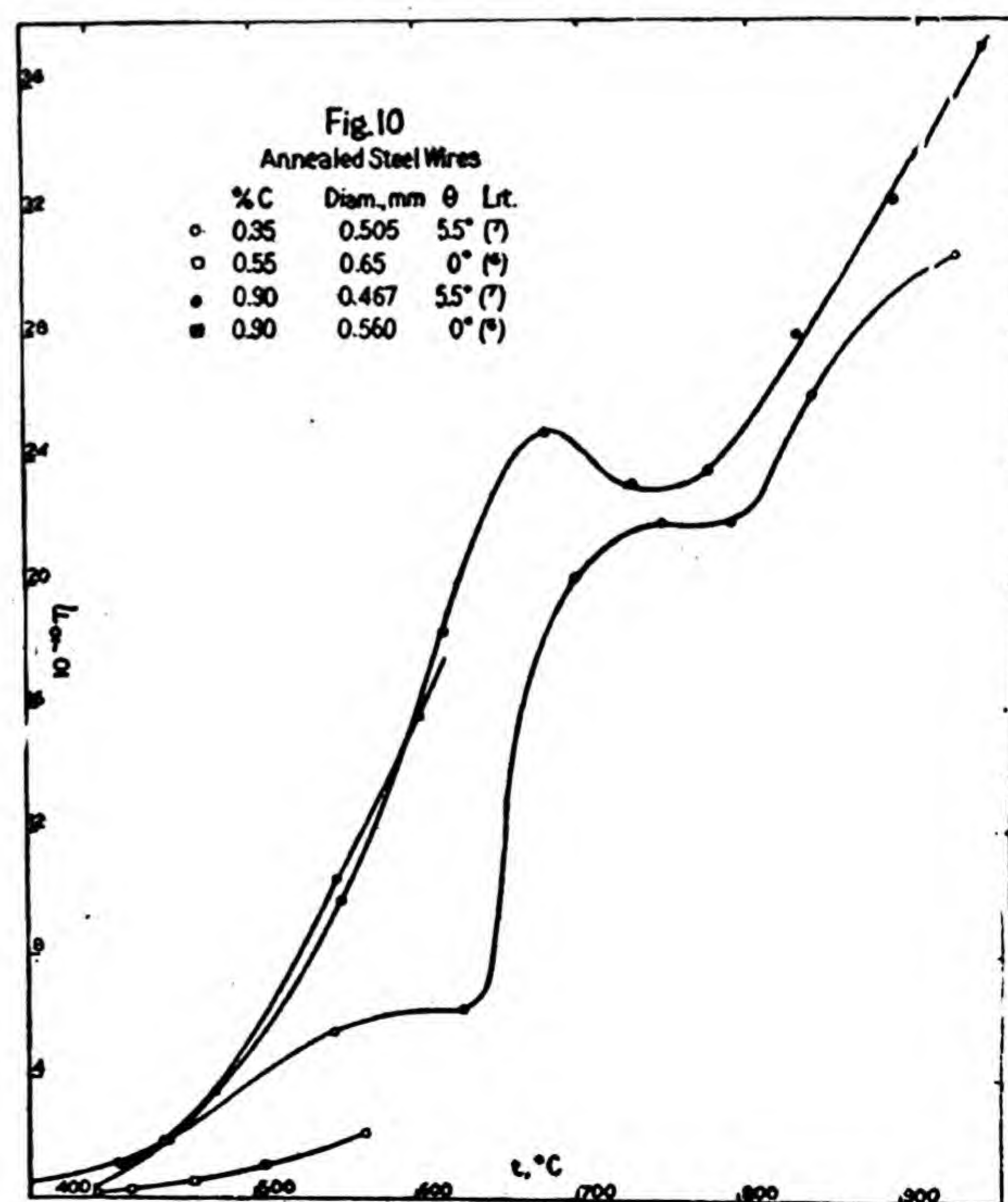
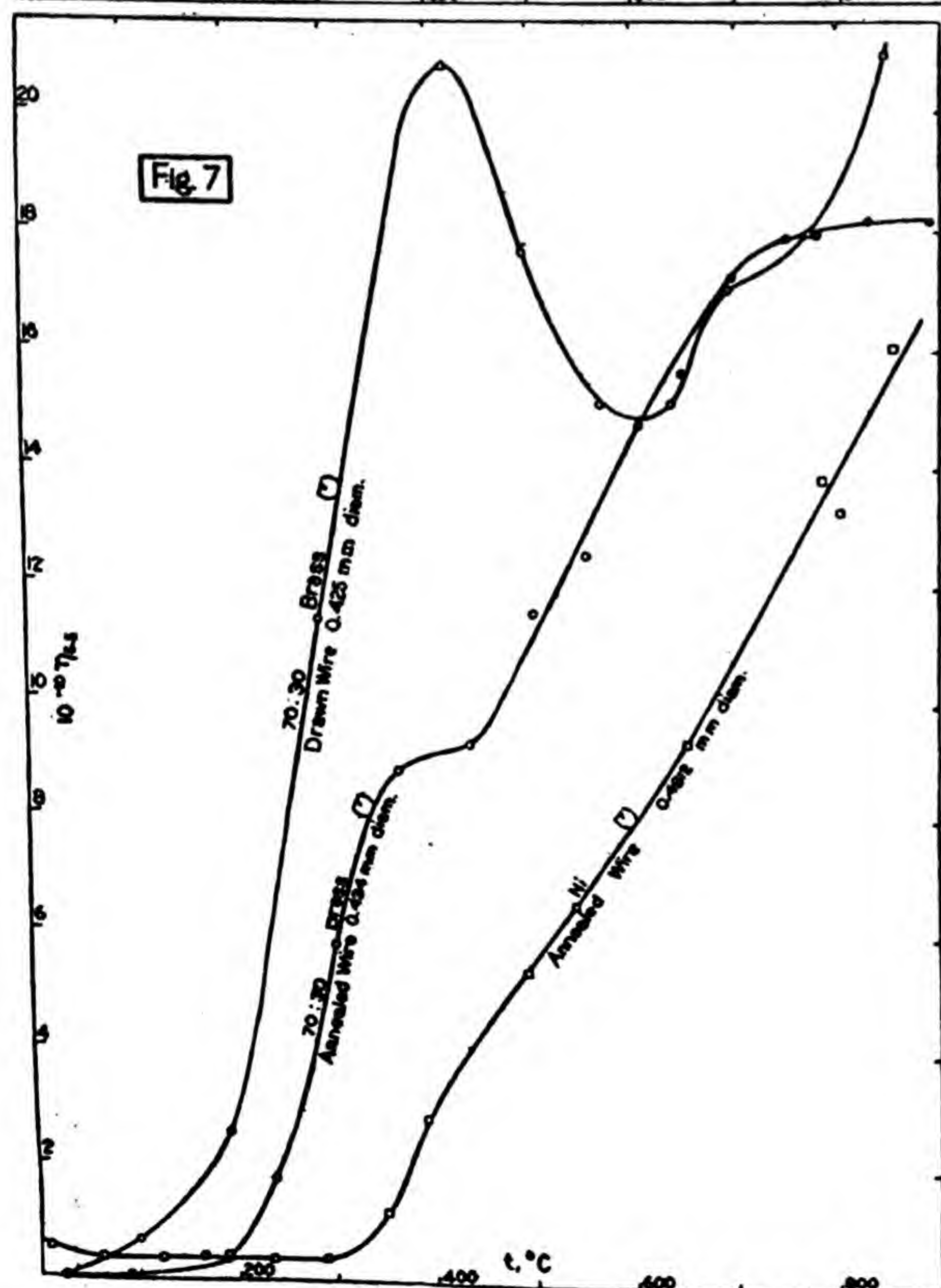
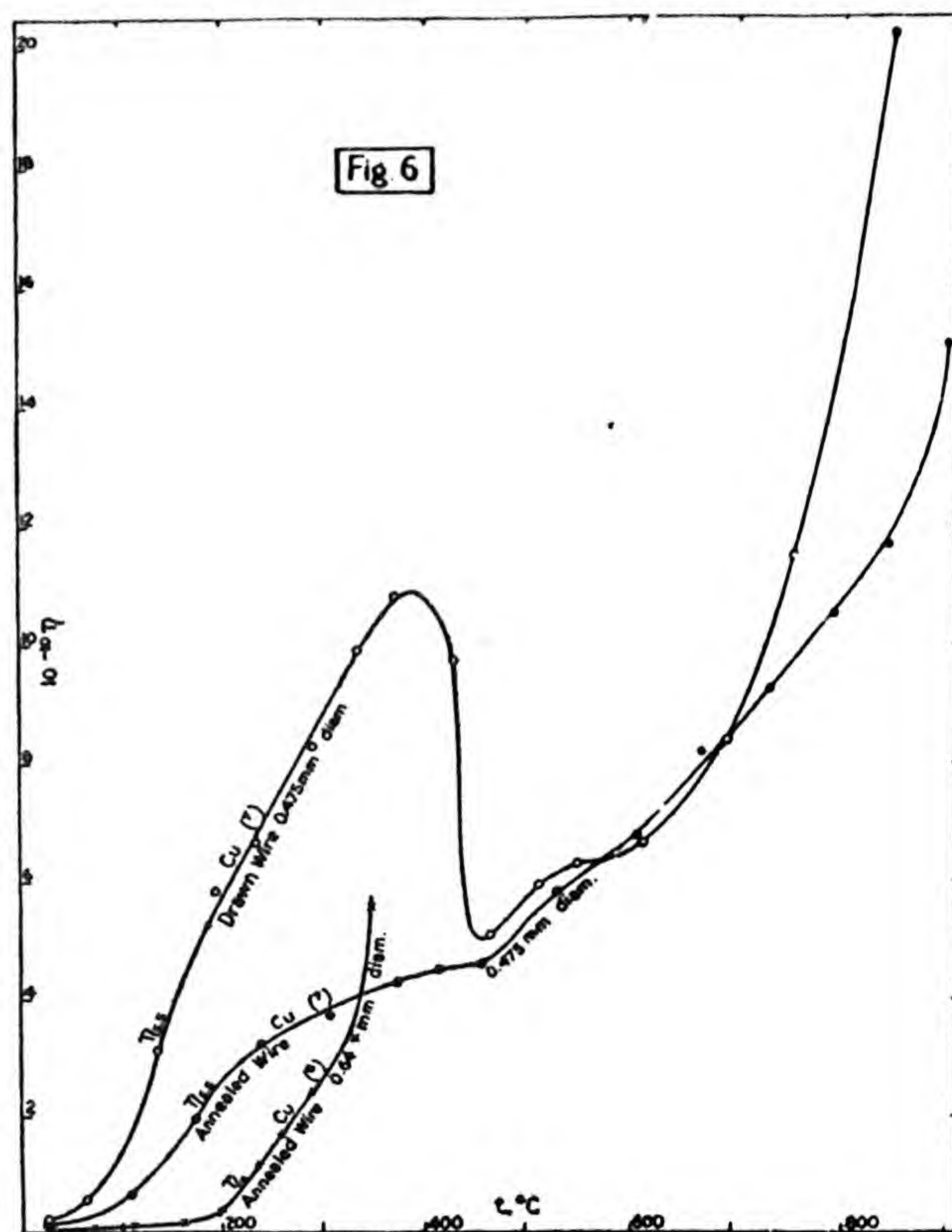
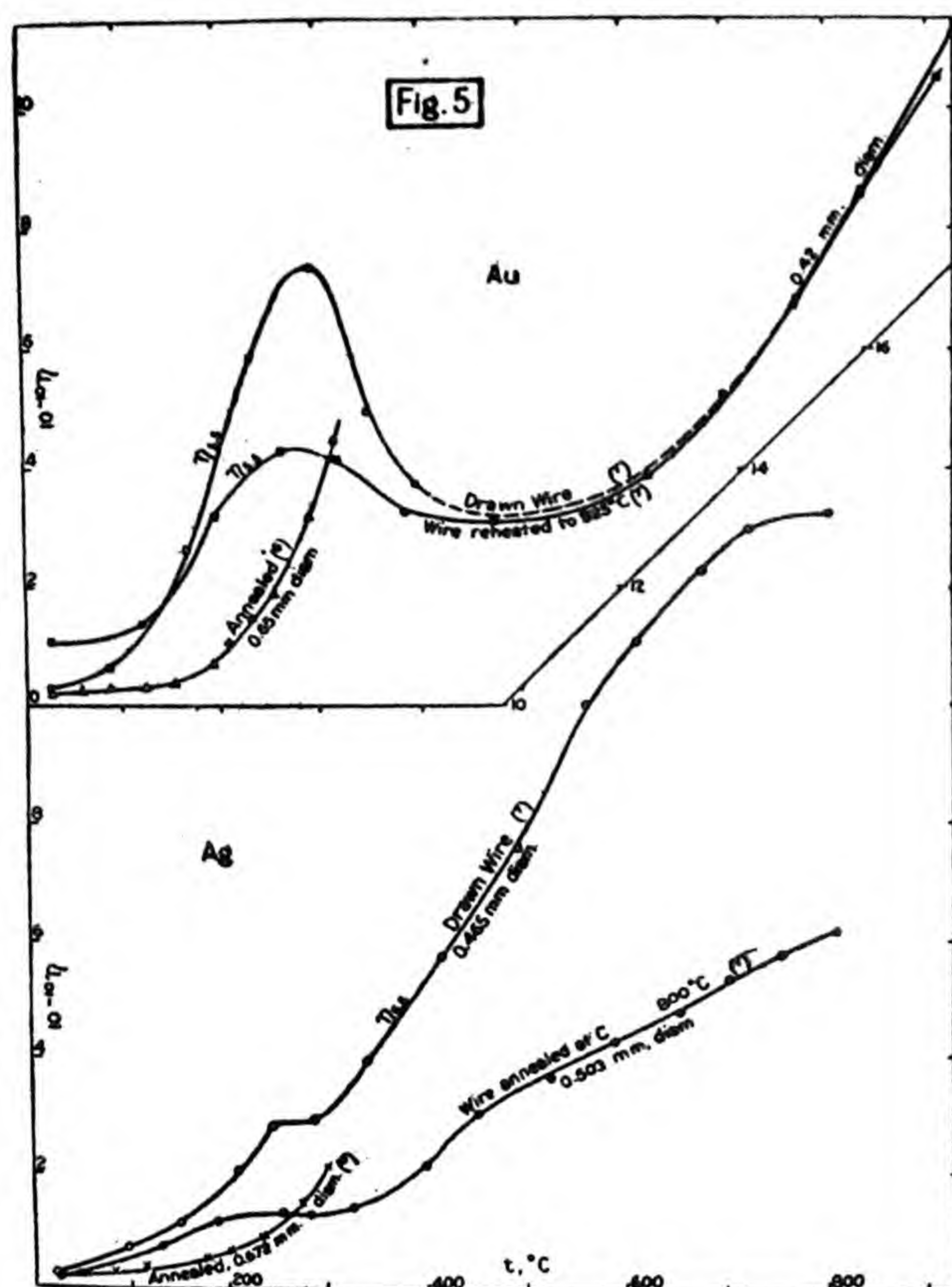
% Composition	$t, ^\circ\text{C}$	$100\eta$	% Composition	$t, ^\circ\text{C}$	$100\eta$
Bi, 58.0; Sn, 42.0	305	1.690	Fe, 96.5; C, 3.5		
	445	1.267	( <sup>15</sup> )	1400	1.75
	606	1.014		1350	2.00
	751	0.886		1300	2.40
Bi, 46.82; Sn, 53.18				1250	2.90
	303	1.642	Fe, 96.0; C, 4.0	1400	1.45
	399	1.336		1350	1.55
	444	1.234		1300	1.75
	601	1.003		1250	2.10
	750	0.881	Hg, 100 (8, 4, 8, 10, 12) (NED)*	-20	1.85
Cd, 100 ( <sup>1</sup> )				0	1.68
(CHMJ)	349	1.44		+20	1.55
	406	1.34		50	1.39
	466	1.27		100	1.21
	506	1.18		150	1.09
	550	1.15		200	1.01
	603	1.10		250	0.96
Cu, 100 ( <sup>14</sup> )	1145	3.41		300	0.92
	1179	3.19		350	0.90
	1187	3.25	Hg, 98; Cd, 2 ( <sup>10</sup> )		
Cu, 85; Sb, 15 ( <sup>14</sup> )	1008	3.77	(TKR)	14.5	1.679
	1108	3.28		20	1.652
Cu, 72; Sb, 28 ( <sup>14</sup> )	737	6.73		40	1.551
	895	4.42	Hg; Cu ( <sup>10</sup> )		
	998	3.60	(TKR)	10	1.671
	1090	3.08		20	1.620
Cu, 61.34; Sb, 38.66 ( <sup>14</sup> )	786	5.41		40	1.520
	890	4.02	Hg, 99; Pb, 1 ( <sup>10</sup> )		
	998	3.24	(TKR)	13	1.664
	1003	3.23		20	1.627
	1090	2.82		30	1.586
Cu, 56.94; Sb, 43.06 ( <sup>14</sup> )	797	4.69		48	1.511
	790	4.71	Hg, 99.4; Zn, 0.6 ( <sup>10</sup> ) (TKR)	13	1.672
	895	3.72		20	1.639
	989	3.14	Pb, 100 ( <sup>14</sup> )	441	2.116
	1087	2.66		456	2.059
Cu, 61.64; Sn, 38.36	803	5.609		551	1.700
Cu, 82.0; Sn, 18.0 ( <sup>14</sup> )	1025	3.62		703	1.349
	1110	3.26		844	1.185
Cu, 71.0; Sn, 29.0 ( <sup>14</sup> )	898	4.34	Pb, 51.3; Bi, 48.7	403	1.571
	1001	3.56		543	1.276
Cu, 61.64; Sn, 38.36 ( <sup>14</sup> )	799	5.19		682	1.100
	900	3.93		833	0.977
	1005	3.16	Pb, 70.0; Bi, 30.0	403	1.728
	1096	2.74		413	1.668
Cu, 50.0; Sn, 50.0 ( <sup>14</sup> )	755	3.65		543	1.370
	903	2.69		704	1.145
	1005	2.28		852	1.021
Fe, 97.5; C, 2.5 ( <sup>15</sup> )	1400	2.25	Pb, 90; Bi, 10	545	1.522
	1350	2.65		550	1.526
	1350	2.025		704	1.274
	1350	2.375		840	1.114
	1300	2.800		867	1.100
			Pb, 83.05; Sb ( <sup>9</sup> )		
			(OFH)	292	2.768
				84.60	2.579
				87.03	2.355
				89.98	2.413
				92.39	2.654

\*  $1/\eta = 59.40 + 0.264t - 0.000341t^2$  (3, 4, 8, 10, 12). At  $p = 1500$  atm.,  $\eta$  is 4.8% greater than at 1 atm. (3).









**Fig. 10**  
**Annealed Steel Wires**

	%C	Diam., mm	θ	Lt.
○	0.35	0.505	55° (?)	
□	0.55	0.65	0° (*)	
●	0.90	0.467	55° (?)	
■	0.90	0.560	0° (*)	



(1) Arpi, 95, 5: 142; 14... (2) Bénard, in Brillouin, *Leçons sur la viscosité des liquides et des gaz*, I: 152. Paris, Gauthier-Villars, 1907. (3) Cohen and Bruins, 64P, 27: 873; 24. 7, 114: 441; 24. (4) Emo, *Thesis*, Torino, 81. 487, 6: 730; 82. (5) Honda and Konno, 159, 11: 435; 22. (6) Iokibe and Sakai, 159, 10: 1; 21. (7) Kikuta, 159, 10: 139; 21. (8) Koch, 8, 14: 1; 81. (9) Plüss, 95, 93: 1; 15.

(10) von Schweidler, 75, 104 IIa: 273; 95. (11) Voigt, 8, 47: 671; 92. (12) Warburg, 8, 20: 367; 70. (13) Sauerwald and Töpler, 93, 157: 117; 26., (14) Bienias and Sauerwald, 93, 161: 51; 27. (15) Thielmann and Wimmer, 77, 47: 389; 27. (16) Chevenard and Portevin, 378, 1926 Spec. No. 434 (17) Hettwer, 75, 134 IIa: 51; 25.

\* For main section of Viscosity of Pure Liquids, see final index.



H<sub>2</sub>O: VARIATION WITH PRESSURE.—(Continued)

<i>t</i> , °C	0	10.3	30	75	<i>P</i>	<i>t</i>	<i>k<sub>i</sub></i>	Lit.
<i>P</i>	<i>k<sub>i</sub></i> (3)							
7 000		+0.52	+1.07	+1.17	600	15	-0.39	(4)
8 000		+0.60	+1.12	+1.25	700	15	-0.33	(4)
9 000			+1.16	+1.36	900	15	-0.30	(4)
10 000			+1.17		100	23	-0.47	(4)
11 000			+1.19		300	23	-0.25	(4)
Variation of <i>k<sub>i</sub></i> with <i>t</i> , <i>P</i> = 413 kg/cm <sup>2</sup> (14)					600	23	-0.17	(4)
<i>t</i> , °C	20	30	40	50	413	20	-0.33	(14)
<i>k<sub>i</sub></i>	-0.33	-0.07	+0.17	+0.34	310	50 to 80	+0.4	(14)
<i>t</i> , °C	60	70	80	90	362	55	+0.6	(14)
<i>k<sub>i</sub></i>	+0.48	+0.62	+0.73	+0.82	516	40	+0.4	(14)

In disagreement with the preceding data, the observations of (29, 37) indicate that at 20°C and pressures not exceeding 150 kg/cm<sup>2</sup>, *k<sub>i</sub>* = -1.7.

## SULFURIC ACID

$\eta = \frac{1}{3(1 - 0.0075t - 0.001t^2)}$  if *t* lies between 11 and 90°C (5, 6, 7, 8, 25, 26). The observations are discordant by  $\pm 5\%$  and more; the composition of the acid is indefinite but presumably between 98 and 100%. At 0°,  $\eta$  is 45% greater than that given by the formula (5); cf. (19); there is only one recorded observation at 0° and none between 0 and 11°.

<i>t</i> , °C	0	11	15	20	30	40	50	60	70	80	90
$10^3\eta$	484	321	299	267	199	145	107	80	62	49	40

## LIQUID CARBON DIOXIDE

Under essentially the pressure of its saturated vapor (36)

<i>t</i> , °C	5	10	15	20	25	29
<i>p</i> , atm.	40.4	45.7	51.6	58.2	65.6	73.6
$10^3\eta$	0.925	0.852	0.784	0.712	0.625	0.539

At higher pressures  
20°C (23)

<i>p</i> , atm.	59	72	83
$10^3\eta$	0.697	0.771	0.823

25.1°C (36)

<i>p</i> , atm.	70	75	85	95	105
$10^3\eta$	0.628	0.665	0.703	0.741	0.800

30°C (23)	<i>p</i> , atm.	72	73	74	76	80
	$10^3\eta$	0.458	0.478	0.495	0.529	0.565

30°C (23)	<i>p</i> , atm.	82	90	96	104	110.5
	$10^3\eta$	0.592	0.643	0.693	0.733	0.770

At the critical point,  $10^3\eta$  is 0.321 (23).

## ORGANIC LIQUIDS

 CHCl<sub>3</sub>, CHLOROFORM

$a = 93.3 \pm 0.5$ ,  $b = 163$ ,  $n = 1.865$ , if *t* lies between -15 and 60° (32); cf. (13, 21, 40)

<i>t</i> , °C	-10	0	+10	20	30	40	50	60
$10^3\eta$	7.86	6.99	6.25	5.63	5.10	4.64	4.24	3.89
<i>P</i>	500	1 000	2 000	4 000				
<i>k<sub>30</sub></i>	5.77	6.25	7.16	8.92				
<i>k<sub>75</sub></i>	6.81	7.22	7.36	7.96				

## CHLOROFORM.—(Continued)

<i>P</i>	6 000	8 000	10 000	
<i>k<sub>30</sub></i>	11.08			
<i>k<sub>75</sub></i>	9.68	12.98	18.19	

 CH<sub>3</sub>OH, METHYL ALCOHOL

$a = 21\,000 \pm 100$ ,  $b = 175.5$ ,  $n = 2.858$ , if *t* lies between 0 and 66°C (32); cf. (2, 10)

<i>t</i> , °C	0	10	20	30	40	50	60
$10^3\eta$	8.08	6.90	5.93	5.15	4.49	3.95	3.49

<i>P</i>	500	1 000	2 000	4 000	
<i>k<sub>30</sub></i>	4.85	4.69	4.66	4.89	
<i>k<sub>75</sub></i>	4.79	4.59	4.40	4.37	

<i>P</i>	6 000	8 000	10 000	12 000	
<i>k<sub>30</sub></i>	5.21	5.78	6.48	7.46	
<i>k<sub>75</sub></i>	4.45	4.72	5.11	5.58	

 C<sub>2</sub>H<sub>5</sub>OH, ETHYL ALCOHOL

$a = (8.20 \pm 0.04) \times 10^7$ ,  $b = 200$ ,  $n = 4.2$ , if *t* lies between 0 and 75°C (32); cf. (2, 10, 11, 33, 34, 35)

<i>t</i> , °C	0	10	20	30	40	50	60	70
$10^3\eta$	17.90	17.52	17.16	16.81	16.47	16.13	15.81	15.49

<i>P</i>	<i>k<sub>0</sub></i>	<i>k<sub>15.1</sub></i>	<i>k<sub>30</sub></i>	<i>k<sub>52.5</sub></i>	<i>k<sub>75</sub></i>	Lit.
400	8.2	8.0				(9)
500			5.59		6.07	(3)
1 000	7.9	8.2	6.4	4.4		(9)
1 000			5.85		6.44	(3)
2 000	9.6	8.6	6.9	5.0		(9)
2 000			6.54		7.22	(3)
2 500	10.2	9.0	7.3	5.5		(9)
4 000			7.85		8.25	(3)
6 000			9.57		9.25	(3)
8 000			11.92		10.60	(3)
10 000			15.25		12.27	(3)
12 000			19.62		14.40	(3)

 (C<sub>2</sub>H<sub>5</sub>)<sub>2</sub>O, ETHYL ETHER

Excepting from 0 to +30°C, only non-overlapping series of data are available for variation of  $\eta$  with *t*; different series do not agree satisfactorily; for each,  $\eta = c(10)^{-3}/[1 + d(10)^{-3} + e(10)^{-6}]$  with average deviation of  $\delta$ . Actual uncertainty exceeds  $\delta$  and, except between 0 and +30°C, may amount to several %.

Range	<i>c</i>	<i>d</i>	<i>e</i>	$\delta$	Lit.
0 to +30°C	2.842	10.40	26.2	0.1%	(32); cf. (10, 18, 27, 40)
0 to +50	2.876*	10.40	26.2	0.2	(15, 16)
+50 to +100	2.520*	4.395	70.2	0.1	(15, 16)
0 to -32	2.898	10.54	26.1	0.1	(41); cf. (20)
-40 to -110	2.793	10.87	25.2	0.5	(41); cf. (20)

<i>t</i> , °C	-110	-100	-90	-80	-60	-40	-30	-20
$10^3\eta$	25.6	16.9	12.4	9.58	6.37	4.61	4.10	3.62
<i>t</i> , °C	-10	0	+20	30	40	60	80	100
$10^3\eta$	3.23	2.842	2.332	2.128	1.97	1.66	1.40	1.18

\* At pressure of saturated vapor.

<i>P</i>	<i>k<sub>0</sub></i> (9)	<i>k<sub>30</sub></i> (9)	<i>k<sub>30</sub></i> (3)	<i>k<sub>34</sub></i> (9)	<i>k<sub>75</sub></i> (3)
500	9.6	9.6	10.92	8.7	8.02
1 000	10.4	10.0	11.09	9.2	8.66
2 000	12.4	11.3	11.32	10.5	9.63
3 000	15.1	14.1	12.0	13.2	10.0
4 000			12.98		10.71
6 000			16.69		12.45
8 000			21.55		14.78
10 000			28.45		17.92
12 000			38.15		21.75



C<sub>6</sub>H<sub>6</sub>, BENZENE

$a = 14.42 \pm 0.03$ ,  $b = 90$ ,  $n = 1.64$ ; if  $t$  lies between 0 and 75°C (27, 32, 40); cf. (10)

$t, ^\circ\text{C} \dots\dots\dots$	0	10	20	30	40	50	60	70
$10^3\eta \dots\dots\dots$	9.00	7.57	6.47	5.61	4.92	4.36	3.893	3.502

For the liquid under the pressure of its saturated vapor the viscosity ( $\eta_{p,t}$ ) may be calculated by means of the equation  $\eta_{p,t} = \eta_{1,t} [1 - 0.0123(p - 1)]$ , if  $t$  lies between 0 and 190°C, where  $\eta_{1,t}$  is value of  $\eta$  at  $t^\circ$  and 1 atm. as computed by the preceding formula ( $\eta_{1,t} = 14.42/(90 + t)^{1.64}$ ), and  $p$  is the pressure (in atm.) of the saturated vapor. Observations between 0 and 100°C lie on the average 1.3% below the computed values, from 100 to 190° observed and computed agree to within 0.1% (15, 16).

$P \dots\dots\dots$	500	1000	2000	3000	Lit.
$k_{30} \dots\dots\dots$	9.80	12.23			} (3)
$k_{75} \dots\dots\dots$	9.80	10.70	12.45	14.70	

VISCOSITY OF AQUEOUS SOLUTIONS OF STRONG ELECTROLYTES

STUART J. BATES AND WARREN P. BAXTER

In the following tables, the concentration  $F$ , is given in formula weights per 1000 g of water, and  $\eta^*$  is the viscosity referred to that of water at the same temperature as unity, except as otherwise noted. Temperature in °C is indicated by the subscript.

Few of the investigators have determined and applied any correction for failure of their viscometers to obey Poiseuille's law exactly. Where feasible, corrections of this nature have therefore been applied.

In general, the last figure given is to be regarded as not being in error by more than 5 units. Where it is given in smaller type, the probable error is somewhat greater, and the last figure may or may not be significant. In cases where it has been possible to estimate the probable error with considerable certainty, this is given. Thus for HCl at 25° and 1*F* the relative viscosity is  $1.060 \pm 0.003$ . This indicates that the probable error for all solutions up to a concentration of 1*F* is about 0.3%.

For some electrolytes, additional data, chiefly at higher or lower temperatures or at higher concentrations than those covered by the tables, may be found by consulting the literature.

Should it be desired to interpolate the viscosity data to other units of concentration, for example to (volume) normal, this may usually be readily done algebraically by noting that, in general, for small changes of concentration, the expression  $\frac{\eta/\eta_0 - 1}{F}$  changes but slowly with the concentration.

\* All interconversions between  $\eta$  and  $\eta/\eta_0$  have been based upon the values for water given on page 10.

AQUEOUS SOLUTIONS CONTAINING A SINGLE STRONG ELECTROLYTE

3-TABLE; Standard Arrangement (v. Vol. III, p. viii)

HCl (27, 45, 66, 69, 91); cf. (103)					
$F$	$\eta_0$ (91)	$F$	$\eta_{25}$	$F$	$\eta_{25}$
1	1.020*	0.1	1.007†	6	1.355
2	1.040	0.25	1.017†	7	1.418
3	1.058	0.5	1.032†	8	1.485
		1	1.060†	9	1.56
	$\eta_{15}$ (91)	2	1.116	11	1.71
1	1.041*	3	1.175	13	1.86
2	1.083	4	1.233	16	2.12
3	1.125	5	1.294		
				* $\pm 0.005$ . † $\pm 0.003$ .	

LITERATURE

(For a key to the periodicals see end of volume)

(1) Bingham and White, 96, 80: 670; 12. (2) Bingham, White, Thomas and Caldwell, 7, 83: 641; 13. (3) Bridgman, 65, 61: 57; 26. (4) Cohen, 8, 45: 666; 92. (5) Drucker and Kassel, 7, 76: 367; 11. (6) Dunstan, 182, 30: 104; 14. (7) Dunstan and Wilson, 4, 91: 83; 07. (8) Dunstan and Wilson, 4, 93: 2179; 09. (9) Faust, 188, 1913: 489. 7, 86: 479; 13. (10) Gartenmeister, 7, 6: 524; 90. (11) Graham, 62, 185: 397; 61. (12) Grotrian, 8, 8: 529; 79. (13) Guye and Friderich, 27, 19: 164; 98. (14) Hauser, 8, 5: 597; 01. (15) Heydweiller, 8, 55: 561; 95. (16) Heydweiller, 8, 59: 193; 96. (17) Hosking, 3, 49: 274; 00. 7: 469; 04. 17: 502; 09. 18: 260; 09. 316, 42: 34; 08. 43: 34; 09. (18) Kendall and Wright, 1, 42: 1776; 20. (19) Kremann and Erlich, 75, 116 II B: 733; 07. (20) Kugelmass, 70, 41: 751, 755; 22. (21) Linebarger, 12, 2: 331; 96. (22) Lyle and Hosking, 3, 3: 487; 02. (23) Phillips, 5, 87: 48; 12. (24) Poiseuille, Paris, Mém. Savants Étrang., 9: 433; 46. 34, 11: 961, 1041; 40. 12: 112; 41. 15: 1167; 42. (25) Poiseuille, 6, 21: 76; 47. (26) Pound, 4, 99: 698; 11. (27) Pribram and Handl, 75, 80 II: 17; 79. (28) Röntgen, 8, 22: 510; 84. (29) Sachs, Diss., Freiburg, 1883. (30) Slotte, 8, 20: 257; 83. (31) Sprung, 8, 189: 1; 76. (32) Thorpe and Rodgers, 62, 185: 397; 94. (33) Tower, 1, 28: 833; 16. (34) Traube, 25, 19: 871; 86. (35) Völlmer, 8, 52: 328; 94. (36) Warburg and von Babo, 8, 17: 390; 82. (37) Warburg and Sachs, 8, 22: 518; 84. (38) Washburn and Williams, 1, 35: 737; 13. (39) White and Twining, 11, 50: 380; 13. (40) Wijkander, 427, 3: 8; 79. (41) Archibald and Ure, 4, 1927: 610.

HClO <sub>4</sub>			HClO <sub>4</sub> —(Cont'd)			HBr.—(Cont'd)		
$F$	$\eta_{15}$ (79)		$M \%$	$\eta_{20}$	$\eta_{50}$	$F$	$\eta_{25}$ (15, 66, 91)	
0.25	1.004		45		6.82	0.25	1.008†	
0.5	1.010		50		6.10	0.5	1.016†	
1.0	1.030		65		3.66	1.0	1.031†	
$F$	$\eta_{25}$ (66)		75		2.45	2	1.058	
0.1	1.005*		80	1.77	2.06	3	1.081	
0.25	1.013*		100	0.76	1.03			
0.5	1.025*		$F$	$\eta_{25}$ (66)				
1.0	1.051*		0.25	1.000				
			0.5	1.003				
			1.0	1.011				
HCO <sub>3</sub> (100)			HBr			HBrO <sub>3</sub> (80)		
$M \%$	$\eta_{20}$	$\eta_{50}$	$F$	$\eta_0$ (91)		$F$	$\eta_{15}$	
5	1.05	1.13		0.987*		0.25	1.016	
10	1.29	1.42		0.974		0.5	1.034	
15	1.74	1.89	2	0.964		0.75	1.053	
20	2.51	2.72	3					
25	3.41	3.64	$F$	HI (88)				
30	4.44	4.77	1	1.014*		$F$	$\eta_{25}$	
35	5.75	6.04	2	1.029		0.1	0.996	
40	6.77	6.77	3	1.045		0.2	0.9954	

H <sub>2</sub> SO <sub>4</sub>							
Values of $\eta$							
$F$	20° (29)	25° (29, 95)	40° (29)	60° (29)	80° (29)	Wt. %	80° (29)
0.1		1.017				10	1.24
0.25		1.043				20	1.55
0.5	1.090	1.091	1.096	1.103	1.126	30	2.05
1.0	1.184	1.185	1.188	1.197	1.211		
2.0	1.405	1.406	1.409	1.41	1.41		
4.0	1.89	1.89	1.89	1.89	1.90		
Values of $\eta$							
Wt. %	0° (67)	10° (3)	20° (29)	25° (3, 18, 19)	40° (3, 29)	60° (29)	75° (67)
10	1.2	1.2	1.211	1.212	1.215	1.223	1.23
20	1.45	1.5	1.535	1.535	1.537	1.54	1.55
30	1.9	1.97	2.02	2.02	2.02	2.02	2.04
40	2.6	2.60		2.68	2.72		2.8



**H<sub>2</sub>SO<sub>4</sub>—(Continued)**

Wt. %	Values of $\eta$					
	0° (67)	10° (3)	20° (29)	25° (3, 18, 19)	40° (3, 29)	75° (67)
50	3.6	3.74		3.83	3.80	4.2
60	6.0	5.8		5.9	5.8	6
70	11	10		10.0	9.3	8
75	17	16		14.3	12.8	10
80				20.3		
86				24.7		
90	26			23.5		14
95	25			21.9		14
98	29	27		23.2	20	15

**HNO<sub>3</sub>**

F	Values of $\eta$				F	$\eta$
	4° (9)	11° (9)	18° (9)	25° (9, 66)		
0.1	0.9956	0.9990	1.0011	1.0035	0.25	1.005*
0.25	0.9927	0.9987	1.0030	1.0074	0.5	1.010*
0.5	0.9903	1.0007	1.0072	1.0133	1	1.019*
1	0.9886	1.0100	1.0197	1.0295	2	1.038*

Wt. %	10° (3)	20° (3, 25)	40° (3)	-15°† (49)
10	1.005	1.035	1.075	
25	1.14	1.20	1.28	0.0272
40	1.46	1.56	1.63	0.0353
50	1.76	1.82	1.91	0.0445
60	2.00	2.03	2.07	0.0562
70	1.99	2.03	2.06	0.0581
80	1.80	1.86	1.94	0.0427
90	1.27	1.35	1.48	
100	0.79	0.89	1.04	

**NH<sub>4</sub>NO<sub>3</sub>**

F	Values of $\eta$				F	$\eta$	F	$\eta$
	10° (84)	20° (84)	40° (84)	50° (84)				
1	0.943	0.965	0.996	1.012	0.25	0.993	4	0.981
2	0.912	0.954	1.005	1.03	0.5	0.986	5	1.009
5	0.920	0.988	1.09	1.13	1.0	0.973	6	1.042
7.5	0.985	1.060	1.19	1.25	2	0.956		
12	1.185	1.295	1.455	1.535	3	0.960		

**NH<sub>4</sub>Cl**

F	Values of $\eta$					
	0° (84)	10° (84)	18°* (2, 12, 72)	25°† (5, 23, 32, 43)	40° (84)	60° (84)
0.25			0.993	0.997		
0.5			0.987	0.994		
1	0.931	0.965	0.978	0.991	1.014	1.033
2	0.891	0.940	0.965	0.988	1.028	1.065
3	0.863	0.924	0.961	0.993	1.045	1.095
4	0.846	0.917	0.963	1.002	1.065	1.13
5			0.970	1.017		
6	0.829	0.924	0.983	1.034	1.12	1.20

 \*  $\pm 0.003$ . †  $\pm 0.005$ .

**NH<sub>4</sub>Br**

F	Values of $\eta$					
	0° (84)	10° (84)	20° (84)	25° (23)	40° (84)	60° (84)
2	0.830	0.890	0.932	0.945	0.987	1.035
3.5	0.784	0.856	0.917	0.934	0.997	1.07
6	0.772	0.854	0.930	0.957	1.045	1.145

 At 25°,  $F = 0.25; 0.993$ .  $F = 0.5; 0.985$ .  $F = 1; 0.970$ .  $F = 5; 0.945$  (23).

**NH<sub>4</sub>I**

F	Values of $\eta$					
	10° (23)	15° (23)	20° (23)	25° (23)	30° (65)	45° (65)
0.25				0.981	0.986	0.991
0.5				0.963	0.971	0.982
1	0.892	0.901	0.917	0.932	0.947*	0.970*
2	0.809	0.840	0.869	0.892		
3.5	0.760	0.808	0.838	0.878		
5	0.764	0.810	0.844	0.894	0.911	
6.5	0.794	0.840	0.878	0.926		
9					1.027	

 \*  $\pm 0.003$ .

**(NH<sub>4</sub>)<sub>2</sub>SO<sub>4</sub>**

F	Values of $\eta$						
	0° (84)	10° (84)	20° (29, 84)	25° (43)	40° (29, 84)	60° (29, 84)	80° (29)
0.25				1.053			
0.5			1.092	1.100	1.112	1.134	1.162
1.0	1.13	1.18	1.198	1.209	1.236	1.269	1.30
2.0			1.452		1.52	1.57	1.61
2.5	1.46	1.55		1.61	1.67	1.74	
4.5			2.32		2.43	2.50	2.56

**H<sub>3</sub>PO<sub>4</sub>**

F	$\eta_{18}$ (57)	$\eta_{25}$ (66)
0.25	1.064	1.062
0.5	1.140	1.130
1	1.294	1.273
2	1.650	

**H<sub>3</sub>AsO<sub>4</sub>**

F	$\eta_{25}$ (66)
0.1	1.023
0.25	1.060
0.5	1.126
1	1.257

**CH<sub>3</sub>NH<sub>2</sub>OH**

F	$\eta_{25}$ (43)
0.1	1.013
0.25	1.034
0.5	1.071
1	1.146

**(CH<sub>3</sub>)<sub>2</sub>NH<sub>2</sub>OH**

F	$\eta_{25}$ (43)
0.1	1.025
0.25	1.064
0.5	1.134
1	1.279

**NH<sub>4</sub>C<sub>2</sub>H<sub>3</sub>O<sub>2</sub>**

F	$\eta_{18}$ (81)
0.25	1.058
0.5	1.117
1	1.238

**(CH<sub>3</sub>)<sub>2</sub>NHOH (43)**

F	$\eta_{25}$
0.1	1.053
0.25	1.139
0.5	1.282
1	1.599

**(CH<sub>3</sub>)<sub>2</sub>NOH (43)**

F	$\eta_{25}$
0.1	1.028
0.25	1.070
0.5	1.140
1	1.286

**CH<sub>3</sub>NH<sub>2</sub>Cl (43)**

F	$\eta_{25}$
0.1	1.005
0.25	1.014
0.5	1.028
1	1.057

**(CH<sub>3</sub>)<sub>2</sub>NH<sub>2</sub>Cl (43)**

F	$\eta_{25}$
0.1	1.010
0.25	1.025
0.5	1.051
1	1.099

**C<sub>2</sub>H<sub>5</sub>NH<sub>2</sub>Cl (43)**

F	$\eta_{25}$
0.1	1.015
0.25	1.038
0.5	1.076
1	1.154

**(CH<sub>3</sub>)<sub>2</sub>NHCl (43)**

F	$\eta_{25}$
0.1	1.039
0.25	1.098
0.5	1.201
1	1.439

**(CH<sub>3</sub>)<sub>2</sub>NCl (43)**

F	$\eta_{25}$
0.1	1.014
0.25	1.037
0.5	1.073
1	1.146

**(C<sub>2</sub>H<sub>5</sub>)<sub>2</sub>NH<sub>2</sub>Cl (43)**

F	$\eta_{25}$
0.1	1.029
0.25	1.073
0.5	1.146
1	1.294

**C<sub>2</sub>H<sub>5</sub>NH<sub>2</sub>Cl (74)**

F	$\eta_{25}$
0.1	1.040
0.25	1.082
0.5	1.150
1	1.292

**C<sub>2</sub>H<sub>5</sub>NH<sub>2</sub>Cl (47)**

F	$\eta_{25}$
0.25	1.140
1	1.647

**(C<sub>2</sub>H<sub>5</sub>)<sub>2</sub>NHCl (43)**

F	$\eta_{25}$
0.1	1.038
0.25	1.098
0.5	1.199
1	1.414

**(C<sub>2</sub>H<sub>5</sub>)<sub>2</sub>NCl (90)**

F	$\eta_{25}$
0.25	1.089
0.5	1.190
1	1.436

**(C<sub>2</sub>H<sub>5</sub>)<sub>2</sub>NCl (90)**

F	$\eta_{25}$
0.25	1.216
0.5	1.494
0.75	1.786

**(C<sub>2</sub>H<sub>5</sub>)<sub>2</sub>NBr (90)**

F	$\eta_{25}$
0.25	1.087
0.5	1.186
1	1.406

**(CH<sub>3</sub>)<sub>2</sub>NI (90)**

F	$\eta_{25}$
0.1	1.005
0.25	1.012
0.5	1.199
0.5	1.458

**(C<sub>2</sub>H<sub>5</sub>)<sub>2</sub>NI (90)**

F	$\eta_{25}$
0.25	1.199
0.5	1.458

**Pb(NO<sub>3</sub>)<sub>2</sub>**

F	$\eta_{18}$ (28)
0.1	1.0165
0.25	1.0435
0.5	1.0971

**Pb(C<sub>2</sub>H<sub>3</sub>O<sub>2</sub>)<sub>2</sub> (47)**

F	$\eta_{25}$
0.25	1.140
1	1.647



<b>TiOH (102)</b> <b>TiNO<sub>3</sub> (95)</b>		<b>CuSO<sub>4</sub></b>		<b>Mn(NO<sub>3</sub>)<sub>2</sub> (32, 95)</b>		<b>CrO<sub>3</sub> (104)</b> <b>H<sub>2</sub>CrO<sub>4</sub> (83)</b>		<b>H<sub>2</sub>CrO<sub>4</sub>—(Cont'd)</b>		<b>CrCl<sub>3</sub> (61)</b>						
<i>F</i>	$\eta_{25}$	<i>F</i>	$\eta_{18} (2)$	$\eta_{25} (4, 32, 95)$	<i>F</i>	$\eta_{25}$	<i>F</i>	$\eta_{10}$	$\eta_{40}$	<i>F</i>	$\eta_{18}$	$\eta_{25}$				
0.1	0.994	0.1	1.063	1.061	0.1	1.033	2	1.12	1.14	7	1.805	1.835				
0.25	0.987	0.25	1.169	1.161	0.25	1.085	4	1.315	1.365	12	2.74	2.755				
<b>ZnCl<sub>2</sub></b>		0.5	1.369	1.357	0.5	1.176	7	1.715	1.765	<i>F</i>						
<i>F</i>	$\eta_{18} (2)$	0.75	1.607	1.598	1	1.370	12	2.675	2.715	$\eta_{15} (78)$						
0.5	1.187	1	1.875		2	1.84	<i>F</i>	$\eta_{30}$	$\eta_{40}$	0.25	1.016					
<i>F</i>	$\eta_{25} (4, 95)$	<b>Cu(NO<sub>3</sub>)<sub>2</sub></b>		$\eta_{25} (4, 95)$	<b>FeCl<sub>3</sub></b>		0.25	1.16	1.17	0.5	1.032					
0.1	1.039	<i>F</i>	$\eta_{18} (2)$	$\eta_{25} (4, 95)$	<i>F</i>	$\eta_{20} (56)$	0.05	1.395	1.42	1	1.064					
0.25	1.096	0.1	1.034	1.030	0.1	1.035	0.1	1.070		2	1.129					
0.5	1.187	0.25	1.089	1.080	0.25	1.073	0.25	1.18		<b>Cr<sub>2</sub>(SO<sub>4</sub>)<sub>3</sub> (26)</b>						
<b>ZnSO<sub>4</sub></b>		0.5	1.188	1.174	0.5	1.18	0.5	1.39		<i>F</i>	$\eta_{10}$	$\eta_{20}$	$\eta_{25}$	$\eta_{40}$	$\eta_{60}$	
<i>F</i>	$\eta_{18} (2)$	1	1.435		0.75	1.64	1.0	1.93		Violet solution						
0.5	1.361	2	2.04	2.01	1.0	1.93	1.5	2.07		0.1	1.222	1.190	1.182	1.165	1.120	
<i>F</i>	$\eta_{25} (4, 32, 95)$	4.5	5.45	5.25	1.5	2.07	2.0	3.64		0.2	1.510	1.485	1.485	1.430	1.33	
0.1	1.063	<i>F</i>	$\eta_{35}$	$\eta_{45}$	3.0	6.9	3.0	6.9		0.3	1.950	1.935	1.920	1.845	1.685	
0.25	1.167	(94)	(94)		4.7	19.0	4.7	19.0		Green solution						
0.5	1.366	2	1.98	1.95	<i>F</i>	$\eta_{25} (43, 56)$	$\eta_{35}$	$\eta_{45}$		0.1	1.145	1.125	1.117	1.110	1.100	
1	1.895	4.5	4.95	4.63	0.05	1.036	1.034			0.2	1.360	1.325	1.310	1.290	1.250	
2	3.78	<b>Cu(CHO<sub>2</sub>)<sub>2</sub> (73)</b>		$\eta_{18}$	0.1	1.072	1.067			0.3	1.71	1.65	1.65	1.605	1.50	
<b>Zn(NO<sub>3</sub>)<sub>2</sub> (95)</b>		<i>F</i>	$\eta_{25}$		0.25	1.18	1.17			<b>(NH<sub>4</sub>)<sub>2</sub>Cr<sub>2</sub>O<sub>7</sub> (82)</b>		<b>MgSO<sub>4</sub></b>		<b>Ca(NO<sub>3</sub>)<sub>2</sub> (58, 95)</b>		
<i>F</i>	$\eta_{25}$	0.05	1.032		0.5	1.37	1.35			<i>F</i>	$\eta_{10}$	$\eta_{20}$	<i>F</i>	$\eta_{18}$	$\eta_{25}$	
0.1	1.030	0.1	1.058		0.75	1.60	1.57			0.25	0.990	1.000	0.1	1.020		
0.25	1.079	0.2	1.108		1.0	1.85	1.80			0.5	0.990	1.011	0.25	1.054		
0.5	1.164	0.3	1.157		1.5	2.45	2.34			1	1.006	1.046	0.5	1.120		
<b>CdCl<sub>2</sub> (95)</b>		<b>Cu(C<sub>2</sub>H<sub>3</sub>O<sub>2</sub>)<sub>2</sub> (73)</b>		$\eta_{18}$	2.0	3.18	3.00			<i>F</i>	$\eta_{30}$	$\eta_{40}$	1	1.290		
0.1	1.023	0.05	1.041		3.0	5.2	3.9			0.25	1.013	1.027	0.5	1.750		
0.25	1.063	0.1	1.081		4.7	11.3	9.8			0.5	1.032	1.055	1	2.450		
0.5	1.132	0.2	1.156		<b>CoCl<sub>2</sub> (54, 95, 99)</b>		$\eta_{25}$			1	1.081	1.111	2	3.95	3.80	
<b>CdSO<sub>4</sub> (95)</b>		<b>Cu(C<sub>2</sub>H<sub>3</sub>O<sub>2</sub>)<sub>2</sub> (73)</b>		$\eta_{18}$	0.1	1.038	1.038			<i>F</i>	$\eta_{40}$	$\eta_{60}$	<b>Ca(C<sub>2</sub>H<sub>3</sub>O<sub>2</sub>)<sub>2</sub> (81)</b>			
0.1	1.060	0.05	1.058		0.25	1.098	1.098			1	1.89		<i>F</i>	$\eta_{18}$	$\eta_{25}$	
0.25	1.158	0.1	1.105		0.5	1.202	1.202			2	3.55		0.25	1.212		
0.5	1.344	0.2	1.200		1	1.432	1.432			<b>Mg(NO<sub>3</sub>)<sub>2</sub></b>			0.5	1.465		
<b>Cd(NO<sub>3</sub>)<sub>2</sub> (95)</b>		<i>F</i>	$\eta_{25}$		0.1	1.408	1.408			<i>F</i>	$\eta_{25} (32)$		1	2.135		
0.1	1.028	0.25	1.008		<b>CoSO<sub>4</sub> (95)</b>		$\eta_{25}$			0.5	1.165		<b>CaCrO<sub>4</sub> (28)</b>			
0.25	1.074	0.5	1.020		0.1	1.060	1.060			1	1.374		<i>F</i>	$\eta_{18}$	$\eta_{25}$	
0.5	1.161	1	1.055		0.25	1.160	1.160			2	1.95		0.05	1.0263		
<b>HgCl<sub>2</sub> (33, 65, 95)</b>		3	1.265		0.5	1.353	1.353			3	2.84		0.1	1.0512		
0.1	1.012	6	1.65		<b>Co(NO<sub>3</sub>)<sub>2</sub> (95)</b>		$\eta_{25}$			<b>Mg(C<sub>2</sub>H<sub>3</sub>O<sub>2</sub>)<sub>2</sub> (68)</b>			0.25	1.1290		
0.25	1.032	12	2.71		0.1	1.028	1.028			<b>MgCrO<sub>4</sub> (82)</b>			0.5	1.272		
<b>Hg(CN)<sub>2</sub></b>		<b>AgTi(NO<sub>3</sub>)<sub>2</sub></b>		0 to 100 % of salt at 100° (64)	0.25	1.074	1.074			<i>F</i>	$\eta$		<b>SrCl<sub>2</sub></b>			
<i>F</i>	$\eta_{18} (65)$	<b>MnCl<sub>2</sub> (32, 95)</b>		$\eta_{25}$	0.5	1.162	1.162			1	10°	20°	40°	<i>F</i>	$\eta_{18} (72)$	$\eta_{25} (32, 95)$
0.1	1.014	<i>F</i>	$\eta_{25}$		<b>Co(CNS)<sub>2</sub> (99)</b>		$\eta_{25}$			2	1.52	1.51	1.49	0.1	1.027	1.027
0.25	1.036	0.1	1.013		<i>F</i>	$\eta_{25}$	$\eta_{25}$			<b>CaCl<sub>2</sub></b>			0.25	1.067	1.069	
<i>F</i>	$\eta_{25} (32, 65)$	0.25	1.034		0.5	1.185	1.185			0.1	$\eta_{10}$	$\eta_{40}$	0.5	1.139	1.146	
0.1	1.013	0.4	1.055		<b>NiCl<sub>2</sub> (95)</b>		$\eta_{25}$			(84)	(84)		1	1.300	1.33	
0.25	1.031	<i>F</i>	$\eta_{45} (65)$		<i>F</i>	$\eta_{25}$	$\eta_{25}$			2	1.72	1.82	2	1.77	1.81	
<b>CuCl<sub>2</sub></b>		0.1	1.012		0.1	1.036	1.036			4	3.48	3.72	3	2.50	2.56	
<i>F</i>	$\eta_{18} (72)$	0.25	1.031		0.25	1.094	1.094			6	9.4	8.2	<i>F</i>	$\eta_{40} (84)$		
0.1	1.040	0.5	1.201	1.208	0.5	1.204	1.204			<i>F</i>	$\eta_{18} (28, 75, 84)$	$\eta_{25} (52, 84, 95)$	0.5	1.16		
0.25	1.100	1	1.425	1.435	<b>NiSO<sub>4</sub> (95)</b>		$\eta_{25}$			0.1	1.0305	1.030	1	1.35		
0.5	1.201	2	1.943	1.942	0.1	1.059	1.059			0.25	1.0750	1.076	2	1.85		
1	1.425	3	2.564		0.25	1.161	1.161			0.5	1.1485	1.155	3	2.63		
2	1.943	<b>MnSO<sub>4</sub> (32, 95)</b>		$\eta_{25}$	0.5	1.361	1.361			1	1.308	1.33	<b>Sr(NO<sub>3</sub>)<sub>2</sub> (95)</b>			
3	2.564	0.1	1.064		<b>Ni(NO<sub>3</sub>)<sub>2</sub> (95)</b>		$\eta_{25}$			2	1.74	1.78	<i>F</i>	$\eta_{25}$	$\eta_{25}$	
		0.25	1.169		0.1	1.032	1.032			4	3.54	3.60	0.1	1.019		
		0.5	1.368		0.25	1.083	1.083			6	9.00	8.5	0.25	1.050		
		1	1.90		0.5	1.177	1.177						0.5	1.112		
		2	3.86													
		3	7.99													



**Sr(C<sub>2</sub>H<sub>3</sub>O<sub>2</sub>)<sub>2</sub> (81)**

F	$\eta_{18}$
0.25	1.212
0.5	1.465
1	2.135

**Ba(OH)<sub>2</sub> (102)**
**BaCl<sub>2</sub>**

F	$\eta_{10}$ (54, 84)	$\eta_{25}$ (54, 84)
0.25	1.045	1.070
0.5	1.095	1.14
1	1.22	1.31
F	$\eta_{18}$ (2, 12, 72)	$\eta_{25}$ (32, 95)
0.1	1.024	1.024
0.25	1.060	1.061
0.5	1.120	1.126
1	1.259	1.285

**BaBr<sub>2</sub> (17)**

F	$\eta_{18}$
0.1	1.018

**Ba(NO<sub>3</sub>)<sub>2</sub> (95)**

F	$\eta_{25}$
0.1	1.017
0.25	1.043

**Ba(C<sub>2</sub>H<sub>3</sub>O<sub>2</sub>)<sub>2</sub> (81)**

F	$\eta_{18}$
0.25	1.202
0.5	1.426
1	2.019

**Ba(CNS)<sub>2</sub> (99)**

F	$\eta_{25}$	$\eta_{75}$
0.5	1.106	1.131

**LiOH (10); cf. (102)**

F	$\eta_0$	$\eta_{25}$
0.5	1.13	1.12
1	1.24	1.23
2	1.67	1.61
4	3.40	2.88
F	$\eta_{50}$	$\eta_{75}$
0.5	1.11	1.10
1	1.22	1.21
2	1.56	1.51
4	2.58	2.30

**LiCl**

F	$\eta_{18}$ (2, 8, 27, 28, 36)	$\eta_{25}$ (27, 32, 62, 70, 95)
0.1	1.0160	1.014
0.25	1.0385	1.035
0.5	1.0747	1.069
1	1.1476	1.142
2	1.298	1.302
3	1.473	1.479
4	1.669	1.673
5	1.891	1.895
6	2.145	2.155
7	2.445	2.455
8	2.801	2.81
9	3.235	3.235
10	3.765	3.73
11	4.405	4.33
12	5.14	5.06
13	6.03	5.94
14	7.14	6.99
15	8.47	8.23
16	9.99	9.60
17	11.80	11.12
20		18.9

**LiCl.—(Cont'd)**

F	$\eta_0$ (36, 97)	$\eta_{18}$ (36, 84)
0.1	1.012*	
0.25	1.033*	
0.5	1.069*	1.071
1	1.129*	1.141
3	1.454	1.465
6	2.09	2.125
9	3.24	3.23
14		7.34
F	$\eta_{10}$ (36, 84)	$\eta_{50}$ (36)
0.5	1.067	1.065
1	1.143	1.148
3	1.495	1.515
6	2.185	2.215
9	3.26	3.28
14	6.69	6.40
F	$\eta_{50}$ (36)	$\eta_{100}$ (36)
0.5	1.068	1.068
1	1.140	1.140
3	1.53	1.53
6	2.24	2.26
9	3.28	3.26
14	6.16	5.92

 \*  $\pm 0.002$ .

**LiClO<sub>3</sub> (70)**

F	$\eta_{25}$
1	1.141
3	1.456
7	2.44
17	9.19
35	61

**LiBr (41, 71)**

F	$\eta_{18}$
0.1	1.015

**LiBrO<sub>3</sub> (89)**

F	$\eta_{20}$
0.1	1.017
0.25	1.044
0.5	1.090
0.8	1.146

**LiIO<sub>3</sub> (28)**

F	$\eta_{18}$
0.05	1.0158
0.2	1.0622
1	1.3815
3	3.020

**Li<sub>2</sub>SO<sub>4</sub>**

$F$	$\eta_{18}^* (2, 28)$
0.05	1.0294
0.1	1.0568
0.25	1.1420
0.5	1.300

$F$	$\eta_{25} (5, 95)$	$\eta_{40} (93)$
0.1	1.053†	1.049†
0.25	1.136†	1.128†
0.5	1.287†	1.27†
1	1.665	1.63

\*  $\pm 0.001$ . †  $\pm 0.005$ .  
‡  $\pm 0.01$ .

 \*  $\pm 0.001$ . †  $\pm 0.005$ .

**LiNO<sub>3</sub>**

F	$\eta_0$ (1)
0.05	1.0038
0.1	1.0070
0.25	1.0166
0.5	1.0323
1	1.0687
2	1.157
3	1.274

**LiNO<sub>3</sub>—(Cont'd)**

F	$\eta_{18}$ (1, 28)	$\eta_{25}$ (1)
0.05	1.0060	1.0060
0.1	1.0109	1.0116
0.25	1.0259	1.0277
0.5	1.0503	1.0534
1	1.0996	1.1063
2	1.2110	1.2230
3	1.341	1.358
4	1.492	1.514
5	1.670	1.694
6	1.874	1.898
9		2.730

**LiC<sub>2</sub>H<sub>3</sub>O<sub>2</sub>**

F	$\eta_{18}$ (81)
0.25	1.115
0.5	1.234
1	1.475

**NaOH**

See also (102)

F	$\eta_{18}$ (57)	$\eta_{25}$ (43)
0.1	1.020	1.023
0.25	1.052	1.055
0.5	1.108	1.110
1	1.234	1.236
2	1.59	
4	2.78	
8	7.04	

**NaCl and NaI: v.**

next column

**NaIO<sub>3</sub> (28)**

F	$\eta_{18}$
0.2	1.0493

**NaHSO<sub>4</sub> (57)**

F	$\eta_{18}$
0.25	1.056
0.5	1.114
1	1.245
2	1.550
5	2.874

**Na<sub>2</sub>SO<sub>4</sub>**

$F$	$\eta_{10}$ (84, 92)	$\eta_{25}$ (2, 84, 92, 95)
0.1	1.036	1.040
0.25	1.096	1.106
0.5	1.217	1.227
0.75	1.372	1.374
1	1.56	
$F$	$\eta_{40}$ (84, 92)	
0.1	1.044	
0.25	1.109	
0.5	1.226	
0.75	1.365	
1	1.54	

**NaN<sub>3</sub> (11)**

F	$\eta_0$	$\eta_{25}$
1.5	1.089	1.126
3	1.294	1.343
5	1.82	1.82
6		2.10

**NaCl**

18° (2, 7, 12, 22, 28, 53); 25° (32, 35, 66, 69, 76); 0°, 80°, 100° (35, 53); 10°, 40°, 60° (35, 53, 84)

F	Values of $\eta$							
	0°	10°	18°	25°	40°	60°	80°	100°
0.1	1.004*	1.006*	1.0085†	1.009†	1.010*	1.012*	1.013*	1.013*
0.25	1.009*	1.016*	1.0205†	1.022†	1.026*	1.030*	1.031*	1.032*
0.5	1.020*	1.032*	1.0405†	1.046†	1.053*	1.060*	1.062*	1.065*
1	1.047*	1.071*	1.0840†	1.094†	1.108*	1.121*	1.127*	1.131*
2	1.147	1.173	1.192	1.205	1.229	1.249	1.26	1.26
3	1.282	1.312	1.329	1.341	1.365	1.39	1.40	1.405
4	1.450	1.481	1.498	1.509	1.524	1.54	1.55	1.555
5		1.692	1.700	1.706	1.713	1.72		

 \*  $\pm 0.005$ .

 †  $\pm 0.001$ .

 ‡  $\pm 0.002$ .

**NaClO<sub>3</sub>**
**NaClO<sub>4</sub>**
**NaBrO<sub>3</sub>**

F	Values of $\eta$					
	15° (79, 84)	25° (66, 84)	40° (84)	25° (66)	15° (80)	20° (89)
0.25	1.012	1.021		1.008	1.022	1.028
0.5	1.028	1.041		1.018	1.047	1.057
1	1.067	1.086	1.10	1.044	1.101	1.117
2.5	1.24	1.265	1.285			
4.5	1.61	1.625	1.64			

**NaBr (84) except at 25° (66)**

F	Values of $\eta$						
	25°	F	10°	20°	25°	40°	60°
0.1	1.005	1	1.029	1.054	1.062*	1.08	1.10
0.25	1.014	2	1.108	1.141	1.154	1.18	1.215
0.5	1.029	3.5	1.29	1.328	1.338	1.365	1.405

 \*  $\pm 0.003$ .

**NaI (84)**

$F$	Values of $\eta$					
	10°	20°	30°	40°	50°	60°
0.5	1.000	1.011	1.017	1.024	1.028	1.033
1.5	1.012	1.042	1.060	1.079	1.092	1.106
4	1.193	1.227	1.253	1.284	1.312	1.334
8	2.035	2.03	2.03	2.045	2.06	2.07

**NaN<sub>3</sub>—(Cont'd)**

F	$\eta_{35}$	$\eta_{50}$
1.5	1.135	1.148
3	1.358	1.385
5	1.81	1.80
6	2.07	2.03

**NaH<sub>2</sub>PO<sub>4</sub> (66)**

F	$\eta_{25}$
0.1	1.040
0.25	1.102
0.5	1.208
1	1.464

**NaH<sub>2</sub>AsO<sub>4</sub> (66)**

F	$\eta_{25}$
0.1	1.040
0.25	1.104
0.5	1.217
1	1.484

**Na<sub>2</sub>CO<sub>3</sub>**

See also (102)

$F$	$\eta_{18}$ (2, 22, 28, 59, 84)	$\eta_{25}$ (66)
0.1	1.0043*	1.005†
0.25	1.0101*	1.012†
0.5	1.0216*	1.025†
1	1.0521*	1.062†
2	1.15	
3	1.27	
5	1.60	
* $\pm 0.0005$ . † $\pm 0.003$ .		

$F$	$\eta_{18}$ (57, 83)	$\eta_{25}$ (43, 83)
0.1	1.048	1.048
0.25	1.126	1.130
0.5	1.274	1.285
1	1.660	
2	3.040	2.93
$\text{Na}_2\text{C}_2\text{O}_4$ (50)		
$F$	$\eta_{35}$	
0.05	1.022	
0.1	1.046	

**Na<sub>2</sub>C<sub>2</sub>O<sub>4</sub> (50)**

F	$\eta_{25}$
0.05	1.022
0.1	1.046

**Na<sub>2</sub>C<sub>2</sub>O<sub>4</sub> (50)**

Acetylenedicarboxylate

F	$\eta_{18}$
0.1	1.127

**NaHCO<sub>2</sub> (66, 81)**

Formate

F	$\eta_{18}$
0.1	1.018
0.25	1.045
0.5	1.094
1	1.202

**NaHCO<sub>3</sub> (57)**

F	$\eta_{18}$
0.25	1.057
0.5	1.118



<b>NaC<sub>2</sub>H<sub>3</sub>O<sub>2</sub> (50)</b> Glycolate		<b>NaC<sub>7</sub>H<sub>5</sub>O<sub>3</sub> (66)</b> Salicylate		<b>Na<sub>2</sub>C<sub>4</sub>H<sub>2</sub>O<sub>4</sub> (50)</b> Fumarate		<b>Na<sub>2</sub>C<sub>8</sub>H<sub>4</sub>O<sub>4</sub> (50)</b> Terephthalate		<b>Na<sub>5</sub>C<sub>11</sub>HO<sub>10</sub>—</b> (Cont'd)			<b>NaC<sub>7</sub>H<sub>4</sub>BrO<sub>2</sub> (50)</b> <i>p</i> -Bromobenzoate				
<i>F</i>	<i>η</i> <sub>25</sub>	<i>F</i>	<i>η</i> <sub>25</sub>	<i>F</i>	<i>η</i> <sub>25</sub>	<i>F</i>	<i>η</i> <sub>25</sub>	<i>F</i>	<i>η</i> <sub>0</sub>	<i>η</i> <sub>25</sub>	<i>F</i>	<i>η</i> <sub>25</sub>			
0.1	1.031	0.1	1.041	0.1	1.060	0.1	1.077	0.005		1.0125	0.1	1.055			
0.25	1.078	0.25	1.102	0.25	1.152	0.25	1.201	0.02		1.0378	0.25	1.141			
0.5	1.155	0.5	1.210	0.5	1.307			0.05	1.0850	1.0879	0.5	1.292			
1	1.325	1	1.468					<i>F</i>	<i>η</i> <sub>50</sub>						
<b>NaC<sub>3</sub>H<sub>5</sub>O<sub>2</sub> (66, 81)</b> Propionate		<b>NaC<sub>8</sub>H<sub>7</sub>O<sub>2</sub> (50)</b> Phenylacetate		<b>Na<sub>2</sub>C<sub>4</sub>H<sub>4</sub>O<sub>4</sub> (50)</b> Succinate		<b>Na<sub>2</sub>C<sub>8</sub>H<sub>12</sub>O<sub>4</sub> (50)</b> Suberate		<b>NaC<sub>2</sub>H<sub>2</sub>ClO<sub>2</sub></b> Chloroacetate			<b>NaC<sub>7</sub>H<sub>4</sub>NO<sub>2</sub> (50)</b> <i>o</i> -Nitrobenzoate				
0.1	1.043	0.1	1.056	0.1	1.068	0.1	1.105	<i>F</i>	<i>η</i> <sub>15</sub>	<i>η</i> <sub>25</sub>	0.1	1.054			
0.25	1.110	0.25	1.145	0.25	1.175	0.25	1.285	(81)	(16)		0.25	1.136			
0.5	1.228	0.5	1.304	0.5	1.375			0.1		1.035	0.5	1.285			
1	1.504	1	1.668					0.2		1.071	1	1.628			
<b>NaC<sub>3</sub>H<sub>5</sub>O<sub>2</sub> (66)</b> Lactate		<b>NaC<sub>8</sub>H<sub>7</sub>O<sub>2</sub> (50)</b> <i>o</i> -Toluate		<b>Na<sub>2</sub>C<sub>4</sub>H<sub>4</sub>O<sub>4</sub> (50)</b> Isosuccinate		<b>Na<sub>2</sub>C<sub>8</sub>H<sub>14</sub>O<sub>4</sub> (50)</b> Azelate		<b>NaC<sub>2</sub>Cl<sub>2</sub>O<sub>2</sub> (81)</b> Trichloroacetate			<b>NaC<sub>7</sub>H<sub>4</sub>NO<sub>2</sub> (66)</b> <i>m</i> -Nitrobenzoate				
0.1	1.040	0.1	1.061	0.1	1.072	0.1	1.164	<i>F</i>	<i>η</i> <sub>15</sub>	<i>η</i> <sub>25</sub>	0.1	1.052			
0.25	1.103	0.25	1.157	0.25	1.177	0.25	1.412	(81)	(16)		0.25	1.130			
0.5	1.216			0.5	1.373			0.5	1.086		0.5	1.269			
1	1.464	<b>NaC<sub>8</sub>H<sub>7</sub>O<sub>2</sub> (50)</b> <i>m</i> -Toluate		<b>Na<sub>2</sub>C<sub>4</sub>H<sub>4</sub>O<sub>4</sub> (50)</b> Malate		<b>Na<sub>2</sub>C<sub>8</sub>H<sub>6</sub>O<sub>7</sub> (50)</b> Citrate		1	1.174	1.364	1	1.606			
		0.1	1.038	0.1	1.062	0.05	1.050	<b>NaC<sub>7</sub>H<sub>4</sub>ClO<sub>2</sub> (50)</b> <i>m</i> -Chlorobenzoate			<b>NaC<sub>7</sub>H<sub>4</sub>NO<sub>2</sub> (50)</b> <i>p</i> -Nitrobenzoate				
<b>NaC<sub>4</sub>H<sub>5</sub>O<sub>6</sub> (57)</b> Acid tartrate		0.25	1.103	0.25	1.167	0.1	1.102	<i>F</i>	<i>η</i> <sub>15</sub>		0.25	1.089			
<i>F</i>	<i>η</i> <sub>18</sub>	0.5	1.248	0.5	1.363	0.25	1.272	0.5	1.215		0.5	1.220			
0.25	1.095	1	1.606					1							
0.5	1.195	<b>NaC<sub>8</sub>H<sub>7</sub>O<sub>2</sub> (50)</b> <i>p</i> -Toluate		<b>Na<sub>2</sub>C<sub>4</sub>H<sub>4</sub>O<sub>6</sub></b> Tartrate		<b>Na<sub>4</sub>C<sub>11</sub>H<sub>2</sub>O<sub>10</sub> (60)</b> Benzenepenta- carboxylate		<b>NaC<sub>7</sub>H<sub>4</sub>BrO<sub>2</sub> (50)</b> <i>m</i> -Bromobenzoate			<b>NaC<sub>5</sub>H<sub>4</sub>NO<sub>2</sub> (50)</b> <i>m</i> -Cyanobenzoate				
		0.1	1.056	<i>F</i>	<i>η</i> <sub>18</sub>	<i>F</i>	<i>η</i> <sub>0</sub>	<i>F</i>	<i>η</i> <sub>25</sub>		0.1	1.050			
<b>NaC<sub>4</sub>H<sub>7</sub>O<sub>2</sub> (66)</b> Butyrate		0.25	1.146	(57)	(50, 62)	0.005		0.1	1.054		0.25	1.128			
<i>F</i>	<i>η</i> <sub>25</sub>	0.5	1.308	0.1	1.047	0.02	1.0314	0.25	1.136		0.5	1.269			
0.1	1.052	1	1.695	0.25	1.137	0.05	1.0748	0.5	1.282						
0.25	1.133	<b>NaC<sub>8</sub>H<sub>7</sub>O<sub>2</sub> (50)</b> Phenoxyacetate		0.5	1.318			1	1.621						
0.5	1.280	0.1	1.056	1	1.790	<b>Na<sub>2</sub>C<sub>8</sub>H<sub>4</sub>O<sub>4</sub> (50)</b> Itaconate		<b>NaC<sub>7</sub>H<sub>4</sub>BrO<sub>2</sub> (50)</b> <i>m</i> -Bromobenzoate			<b>NaC<sub>5</sub>H<sub>4</sub>NO<sub>2</sub> (50)</b> <i>m</i> -Cyanobenzoate				
1	1.620	0.25	1.143	<i>F</i>	<i>η</i> <sub>25</sub>	0.1	1.094	0.1	1.053		0.25	1.128			
<b>NaC<sub>4</sub>H<sub>7</sub>O<sub>2</sub> (66)</b> Isobutyrate		0.5	1.294	0.1	1.094	0.25	1.211	0.25	1.139		0.5	1.269			
0.1	1.056	1	1.654	0.25	1.146	0.5	1.365	0.5	1.293						
0.25	1.140	<b>NaC<sub>8</sub>H<sub>7</sub>O<sub>2</sub> (50)</b> Anisate		0.5	1.322	<b>Na<sub>2</sub>C<sub>8</sub>H<sub>4</sub>O<sub>4</sub> (50)</b> Citraconate		<b>Na<sub>2</sub>O.xSiO<sub>2</sub> (86)</b> Viscosity in centipoises at 20°C							
0.5	1.287	0.1	1.055	0.1	1.076										
1	1.627	0.25	1.142	0.25	1.191										
<b>NaC<sub>5</sub>H<sub>7</sub>O<sub>2</sub> (66)</b> Isovalerate		0.5	1.302	0.5	1.409										
0.1	1.060	<b>NaC<sub>8</sub>H<sub>7</sub>O<sub>2</sub> (50)</b> Phenylglycolate		<b>Na<sub>2</sub>C<sub>8</sub>H<sub>4</sub>O<sub>4</sub> (50)</b> Mesaconate											
0.25	1.153	0.1	1.055	0.1	1.074										
0.5	1.316	0.25	1.143	0.25	1.187										
<b>NaC<sub>8</sub>H<sub>11</sub>O<sub>2</sub> (66)</b> Isocaproate		0.5	1.295	0.5	1.405										
0.1	1.063	1	1.658	<b>Na<sub>2</sub>C<sub>8</sub>H<sub>4</sub>O<sub>4</sub> (50)</b> Pyrotartrate											
0.25	1.166	<b>NaC<sub>8</sub>H<sub>7</sub>O<sub>2</sub> (50)</b> Cinnamate		0.1	1.084										
0.5	1.355	0.1	1.054	0.25	1.214										
<b>NaC<sub>7</sub>H<sub>5</sub>O<sub>2</sub> (66)</b> Benzoate		0.25	1.154	0.5	1.457										
0.1	1.050	0.5	1.334	<b>Na<sub>2</sub>C<sub>8</sub>H<sub>4</sub>O<sub>4</sub> (50)</b> Adipate											
0.25	1.127	<b>NaC<sub>8</sub>H<sub>7</sub>O<sub>2</sub> (50)</b> Hydrocinnamate		0.1	1.088										
0.5	1.264	0.1	1.065	0.25	1.230										
1	1.581	0.25	1.165	0.5	1.526										
<b>NaC<sub>7</sub>H<sub>5</sub>O<sub>2</sub> (50)</b> <i>m</i> -Hydroxybenzoate		0.5	1.337	<b>Na<sub>2</sub>C<sub>8</sub>H<sub>4</sub>O<sub>4</sub> (50)</b> Phthalate											
0.1	1.030	1	1.773	0.1	1.085										
0.25	1.086	<b>Na<sub>2</sub>C<sub>8</sub>H<sub>4</sub>O<sub>4</sub> (50)</b> Malonate		0.25	1.219										
0.5	1.220	0.1	1.034	0.5	1.464										
1	1.608	0.25	1.107	<b>Na<sub>2</sub>C<sub>8</sub>H<sub>4</sub>O<sub>4</sub> (50)</b> Isophthalate											
<b>NaC<sub>7</sub>H<sub>5</sub>O<sub>2</sub> (50)</b> <i>p</i> -Hydroxybenzoate		0.5	1.252	0.1	1.080										
0.1	1.050	<b>Na<sub>2</sub>C<sub>8</sub>H<sub>4</sub>O<sub>4</sub> (50)</b> Maleate		0.25	1.208										
0.25	1.129	0.1	1.035	0.5	1.457										
0.5	1.277	0.25	1.109												
1	1.653	0.5	1.270												

Viscosity in centipoises at 20°C

The solutions employed in determining the data for the following table were commercial solutions of sodium silicate. The only sample completely analyzed was Na<sub>2</sub>O.2.06SiO<sub>2</sub>; for this the following analysis is given: Na<sub>2</sub>O, 18.42%; SiO<sub>2</sub>, 36.84%; Al<sub>2</sub>O<sub>3</sub>, 0.23%; Fe<sub>2</sub>O<sub>3</sub>, 0.16%; CaO, 0.14%; MgO, 0.05%. The compositions given in the table below refer to the percentages by weight of Na<sub>2</sub>O.xSiO<sub>2</sub>. For given values of *x* the original data lie on fairly smooth curves which were interpolated to round concentrations. But for a given percentage composition, particularly in the less concentrated solutions, the viscosity data considered as a function of *x* are quite irregular and it did not seem practicable to smooth them. This effect may be due to varying amounts of impurities in the different solutions.

<i>x</i>	3.90	3.36	2.44	2.06	1.69
3.0	3.3	4.2	3	3	
5.0	4.4	5.5	3.5	4.5	3
10.0	6.5	7.3	5.2	7.5	5.5
15.0	9.0	9.0	7.0	10.0	7.5
20.0	12	12	9	12	10.5
25.0	18	16	12	16	15
28.0	28	22	15	19	19
30.0	49	27	19	22	23
32.0	180	37	24	27	29
33.0	800	44	27	31	34
33.60	7 026				
34.0		55	30	35	39
36.0		120	43	48	58
38.0		270	72	70	95
39.0		460	95	90	120



**Na<sub>2</sub>O.xSiO<sub>2</sub>.—(Continued)**

$x$	2.44	2.06	1.69	$x$	
40.0	130	120	150	50.76	8 496*
42.0	210	190	250	51.60	6 115†
44	400	310	430	52.36	22 900*
46	900	550	750	55.26	87 080†
47		750	1050		

 \*  $x = 1.69$ . †  $x = 2.06$ .

**Viscosity at 25° (53.5)**

$F$	$x$	0	0.5	1.0	2.0	2.5
0.5		1.22	1.28	1.31	1.42	1.49
1.0		1.50	1.70	1.86	2.18	2.50
1.25		1.67	1.93	2.21	2.81	3.43
1.5		1.86	2.30		3.80	4.70

$F$	$x$	3.0	3.3	3.8	3.95	4.2
0.5		1.61	1.68	1.79	1.90	1.87
1.0		3.19	3.48	4.87	5.49	6.77
1.25		4.60	5.42	9.79	13.4	
1.5		7.32	9.38	27.65	104	

 **$F = 1.5$** 

$x$	$t, ^\circ\text{C}$	20	25	40
0.5		2.35	2.30	2.15
2.0		3.95	3.80	3.33
3.95		121.6	103.6	50.1

There is considerable discrepancy between the values at 20° and 25°, probably due to the difference in previous history of the solutions.

**Na<sub>2</sub>SiO<sub>4</sub> (51)**

$F$	$\eta_{30}$
1	2.89

**Na<sub>2</sub>CrO<sub>4</sub> (82)**

$F$	$\eta_{10}$	$\eta_{15}$ (78)
0.1		1.039
0.25		1.101
0.5	1.24	1.209
1	1.66	
$F$	$\eta_{30}$	$\eta_{30}$
0.5	1.25	1.255
1	1.65	1.645
$F$	$\eta_{40}$	
0.5	1.26	
1	1.645	

**Na<sub>2</sub>Cr<sub>2</sub>O<sub>7</sub> (78)**

$F$	$\eta_{15}$
0.1	1.020
0.25	1.050
$F$	$\eta_{30}$
1	1.645

**KOH**

See also (102)

 **$\eta_{15}$  (57)**

$F$	$\eta_{15}$
0.1	1.009
0.25	1.024
0.5	1.050
1	1.106
2	1.230
4	1.541
7.5	2.325

**KOH.—(Cont'd)**

$F$	$\eta_{25}$	$\eta_{60}$
	(43)	(24)
0.1	1.013	1.013
0.25	1.031	1.032
0.5	1.064	1.065
1	1.128	1.134
2	1.268	1.275

**KF (72)**

$F$	$\eta_{18}$
0.2	1.0268
0.5	1.0674
1.0	1.1348
1.5	1.2060
3.0	1.462
6.0	2.083

**KCl**

0° (91, 97); 15° (6, 12, 65, 91); 18° (2, 6, 12, 22, 28, 59, 84, 98); 25° (31, 69, 91, 95); 35 and 45° (65, 84)

$F$	Values of $\eta$					
	0°	15°	18°	25°	35°	45°
0.1	0.9945*	0.997†	0.9982*	0.999†	1.001†	1.003†
0.25	0.9805*	0.991†	0.9949*	0.998†	1.003†	1.008†
0.5	0.9575*	0.984†	0.9898*	0.997†	1.007†	1.015†
0.75	0.9423*	0.978†	0.9849*	0.996†	1.011†	1.023†
1.0	0.9286*	0.974†	0.9816*	0.995†	1.015†	1.031†
1.5	0.9095†	0.969†	0.980†	0.997†	1.0255†	1.0485†
2.0	0.8955†	0.968†	0.982†	1.002†	1.0355†	1.0655†
2.5	0.895†	0.970†	0.987†	1.010†	1.055†	1.0855†

**KCl.—(Continued)**

$F$	Values of $\eta$					
	0°	15°	18°	25°	35°	45°
3.0	0.8855†	0.975†	0.994†	1.021†	1.0655†	1.1055†
4.0	0.8855†	0.994†	1.017†	1.050†	1.105†	1.1455†

 \*  $\pm 0.001$ . †  $\pm 0.002$ . ‡  $\pm 0.003$ . §  $\pm 0.01$ .

**KClO<sub>3</sub> (65, 79); for 18° (72)**

$F$	Values of $\eta$				
	15°	18°	25°	35°	45°
0.1	0.994*	0.998†	0.999*	0.999*	1.002†
0.2	0.990*	0.995†	0.998*	0.999*	1.004†
0.3	0.987*	0.992†	0.996*	1.000*	1.006†
0.5	0.981	0.985			

 \*  $\pm 0.003$ . †  $\pm 0.002$ . ‡  $\pm 0.005$ .

**KBr (84); for 0° (91); for 18° (22, 72, 84, 91); for 25° (31, 91)**

$F$	Values of $\eta$						
	0°	5°	10°	18°	25°	40°	50°
0.25				0.986*	0.992		
0.5				0.974*	0.984		
1	0.913	0.925	0.94	0.954*	0.969	1.005	1.02
2	0.845	0.875	0.905	0.930*	0.959	1.025	1.05
3	0.817				0.967		
4.5		0.87	0.905	0.952	1.007	1.10	1.145
5.5					1.050		

 \*  $\pm 0.003$ .

**KI for 0° (40, 91); for 5°, 10°, 40°, 50°, 60° (84); for 18° (2, 22, 28, 84); for 25° (31, 40, 84, 91)**

$F$	Values of $\eta$							
	0°	5°	10°	18°*	25°	40°	50°	60°
0.1	0.982*			0.9908	0.993			
0.25				0.9768	0.981			
0.5		0.940	0.947	0.9561	0.964	0.990	1.001	1.009
1	0.860	0.898	0.906	0.9228	0.936	0.983	1.004	1.020
2	0.787			0.898	0.915			
3	0.755	0.81	0.845	0.892	0.916	0.989	1.035	1.075
5		0.805	0.855	0.916	0.951	1.048	1.105	1.16
7		0.865	0.91	0.978	1.03	1.149	1.21	1.285
7.5				1.003				
9					1.20			

 \*  $\pm 0.001$ .

$F$	KBrO <sub>3</sub> (80)		KIO <sub>3</sub> (28, 72)			KHSO <sub>4</sub> (57)			
	0.25	0.1	0.2	0.3	0.25	0.5	1	2	
$\eta_{15}$	0.994								
$\eta_{18}$		1.0141	1.0278	1.042	1.035	1.071	1.144	1.310	

**K<sub>2</sub>SO<sub>4</sub> (84, 92); for 18° (2, 28, 57, 84, 92); for 25° (95)**

$F$	Values of $\eta$					
	10°*	18°†	25°*	30°*	40°*	50°*
0.05		1.011	1.011			
0.1	1.017	1.021	1.022	1.023	1.024	1.025
0.25	1.044	1.051	1.054	1.057	1.062	1.065
0.5	1.087	1.0995	1.109	1.118	1.128	1.136

 \*  $\pm 0.005$ . †  $\pm 0.001$ .

**KN<sub>3</sub> (11)**

$F$	Values of $\eta$				
	0°	25°	35°	50°	75°
1	0.945	1.006	1.019	1.035	1.053
3	0.926	1.043	1.075	1.120	1.171
4	0.939	1.077	1.116	1.172	1.237
6		1.188	1.231	1.297	1.383



KNO <sub>3</sub>		
F	$\eta_{10}$ (84)	$\eta_{40}$ (84)
1	0.948	1.01
2	0.94	1.04
F	$\eta_{18}$ (2, 22, 28, 59, 84)	$\eta_{25}$ (84, 95)
0.1	0.9941	0.995
0.25	0.9857	0.989
0.5	0.9748	0.982
1	0.9630	0.976
2	0.975	0.999
F	$\eta_{40}$ (84)	$\eta_{60}$ (84)
1	1.02	1.035
2	1.06	1.085

K <sub>3</sub> PO <sub>4</sub> (57)		
F	$\eta_{18}$	
0.1	1.050	
0.25	1.130	
0.5	1.292	
1	1.721	

K <sub>2</sub> HPO <sub>4</sub> (57)		
F	$\eta_{18}$	
0.1	1.034	
0.25	1.091	
0.5	1.201	
1	1.513	
2	2.18	

KH <sub>2</sub> PO <sub>4</sub> (57)		
F	$\eta_{18}$	
0.25	1.064	
0.5	1.137	
1	1.291	

K <sub>2</sub> CO <sub>3</sub> (2, 57, 72)		
F	$\eta_{18}$	$\eta_{25}$ † (43)
0.1	1.029*	1.031
0.25	1.073*	1.078
0.5	1.152*	1.165
1	1.340*	
2	1.82	
3	2.46	
4	3.34	

\*  $\pm 0.003$ .  
†  $\pm 0.005$ .

K <sub>2</sub> C <sub>2</sub> O <sub>4</sub> (28, 57)		
Oxalate		
F	$\eta_{18}$	
0.05	1.0125	
0.1	1.0235	
0.25	1.0545	
0.5	1.110	
1	1.225	

KHCO <sub>3</sub> (57)		
F	$\eta_{18}$	
0.25	1.029	
0.5	1.059	
1	1.123	
2	1.261	

KHCO <sub>3</sub> (81)		
Formate		
F	$\eta_{18}$	
0.5	1.039	

KC <sub>2</sub> H <sub>3</sub> O <sub>2</sub> (2, 72, 81)		
Acetate		
F	$\eta_{18}$	
0.1	1.028	
0.25	1.064	
0.5	1.125	
1	1.248	
2	1.515	
3	1.817	
4	2.172	

KC <sub>2</sub> H <sub>3</sub> O <sub>2</sub> (81)		
Propionate		
F	$\eta_{18}$	
0.5	1.164	

K <sub>2</sub> C <sub>4</sub> H <sub>4</sub> O <sub>6</sub> (44, 57)		
Tartrate		
F	$\eta_{18}$	
0.25	1.078	
0.5	1.183	
0.75	1.30	
1.5	1.74	

KC <sub>2</sub> Cl <sub>3</sub> O <sub>2</sub> (81)		
Trichloroacetate		
F	$\eta_{18}$	
0.5	1.164	

KC <sub>2</sub> H <sub>3</sub> ClO (81)		
Chloroacetate		
F	$\eta_{18}$	
0.5	1.106	

KCNS		
F	$\eta_{18}$ (72)	
0.1	0.997	
0.25	0.989	
0.5	0.977	
1	0.960	
2	0.950	
5	1.036	

K <sub>3</sub> Fe(CN) <sub>6</sub>		
F	$\eta_{18}$ (65)	
0.1	0.988	
0.25	0.990	

K <sub>3</sub> Fe(CN) <sub>6</sub>		
F	$\eta_{18}$ (65, 95)	
0.1	1.007*	1.016*
0.25	1.022*	1.044*
0.5	1.062*	1.098*

K <sub>2</sub> CrO <sub>4</sub>		
F	$\eta_{18}$ (72, 78)	
0.1	1.105	
0.25	1.038	
0.5	1.078	
1	1.13	1.174
2	1.35	1.425

K <sub>2</sub> CrO <sub>4</sub>		
F	$\eta_{40}$ (84)	$\eta_{60}$ (84)
1	1.20	1.23
2	1.47	1.51

K <sub>2</sub> CrO <sub>4</sub> (Cont'd)		
F	$\eta_{40}$ (84)	
1	1.25	
2	1.54	

K <sub>2</sub> Cr <sub>2</sub> O <sub>7</sub>		
F	$\eta_{10}$ (82)	$\eta_{25}$ (43)
0.1	0.993	1.001
0.25	0.986	1.006

KNaC <sub>4</sub> H <sub>4</sub> O <sub>6</sub> (57)		
Tartrate		
F	$\eta_{18}$	
0.25	1.108	
0.5	1.246	
0.75	1.410	
1.5	2.05	

RbOH (20)		
F	$\eta_{25}$	
0.1	1.009	
0.25	1.023	
0.5	1.048	
1	1.103	

RbCl		
F	$\eta_{18}$ (76)	$\eta_{10}$ (76)
0.25	0.975	0.982
0.5	0.955	0.967
1	0.923	0.941

RbBr (14)		
F	$\eta_{18}$ (72, 76)	$\eta_{25}$ (76, 95)
0.25	0.990†	0.995
0.5	0.980†	0.990
1	0.965†	0.983
2	0.943	

RbI (23)		
F	$\eta_{25}$	$\eta_{35}$
0.1	0.995	0.999
0.25	0.989	0.998
0.5	0.979	0.997

Rb <sub>2</sub> SO <sub>4</sub> ; v. next column		
F	$\eta_{18}$ (72)	$\eta_{25}$ (39, 95)
0.25	0.986*	0.992
0.5	0.973*	0.985
1	0.952*	0.975
2	0.927	

CsCl		
F	$\eta_{18}$ (72)	$\eta_{25}$ (39, 95)
0.25	0.986*	0.992
0.5	0.973*	0.985
1	0.952*	0.975
2	0.927	

Cs <sub>2</sub> SO <sub>4</sub> (93)		
F	$\eta_{10}$	$\eta_{20}$
0.1	1.005	1.011
0.25	1.016	1.03
0.5	1.040	1.07
1.0	1.113	1.19

Cs <sub>2</sub> SO <sub>4</sub> (93)		
F	$\eta_{10}$	$\eta_{20}$
0.1	1.008	1.012
0.25	1.022	1.031
0.5	1.047	1.067
1.0	1.105	1.145

CsNO <sub>3</sub> (55)		
F	$\eta_{10}$	$\eta_{20}$
0.1	1.008	1.012
0.25	1.022	1.031
0.5	1.047	1.067
1.0	1.105	1.145

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0.1	1.008	1.012
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0.5	1.047	1.067
1.0	1.105	1.145

CsNO <sub>3</sub> (55)		
F	$\eta_{10}$	$\eta_{20}$
0.1	1.008	1.012
0.25	1.022	1.031
0.5	1.047	1.067
1.0	1.105	1.145

# AQUEOUS SOLUTIONS CONTAINING TWO STRONG ELECTROLYTES

B-TABLE; Standard Arrangement (v. Vol. III, p. viii)

A	B	t, °C	Lit.
HCl.....	CdCl <sub>2</sub>	25	(43)
	HgCl <sub>2</sub>	25	(43, 101)
	CuCl <sub>2</sub>	25	(101)
	FeCl <sub>2</sub>	25	(43)
	CoCl <sub>2</sub>	25	(101); cf. (103)
	NaCl	25	(69)
	KCl	25	(69)
H <sub>2</sub> SO <sub>4</sub> .....	HNO <sub>3</sub>	10	(3)
		20	(3)
		40	(3)
	K <sub>2</sub> Cr <sub>2</sub> O <sub>7</sub>	25	(43)
HNO <sub>3</sub> .....	Ba(NO <sub>3</sub> ) <sub>2</sub>	25	(43)
NH <sub>4</sub> NO <sub>3</sub> .....	NH <sub>4</sub> Cl	25	(43)
	Pb(NO <sub>3</sub> ) <sub>2</sub>	25	(43)
	Ba(NO <sub>3</sub> ) <sub>2</sub>	25	(43)
	NaNO <sub>3</sub>	25	(43)
	KNO <sub>3</sub>	25	(43)
NH <sub>4</sub> Cl.....	FeCl <sub>3</sub>	25	(43)
	BaCl <sub>2</sub>	25	(43)
	NaCl	15	(12)
		20	(12)
	KCl	15	(12)
		20	(12)
		25	(43)
(NH <sub>4</sub> ) <sub>2</sub> SO <sub>4</sub> .....	CuSO <sub>4</sub>	25	(43)
	MnSO <sub>4</sub>	25	(43)
	Al <sub>2</sub> (SO <sub>4</sub> ) <sub>3</sub>	25	(43)
	K <sub>2</sub> SO <sub>4</sub>	25	(43)



B-TABLE.—(Continued)

A	B	t, °C	Lit.
Pb(NO <sub>3</sub> ) <sub>2</sub> .....	NaNO <sub>3</sub>	25	(43)
	KNO <sub>3</sub>	25	(43)
CuCl <sub>2</sub> .....	MgCl <sub>2</sub>	25	(101)
	LiCl	25	(101)
	NaCl	25	(101)
	KCl	25	(101)
CuSO <sub>4</sub> .....	MnSO <sub>4</sub>	25	(43)
	Na <sub>2</sub> SO <sub>4</sub>	25	(43)
	K <sub>2</sub> SO <sub>4</sub>	25	(43)
MnSO <sub>4</sub> .....	Na <sub>2</sub> SO <sub>4</sub>	25	(43)
	K <sub>2</sub> SO <sub>4</sub>	25	(43)
CoCl <sub>2</sub> .....	MgCl <sub>2</sub>	25	(101)
	LiCl	25	(101)
	NaCl	25	(101)
	KCl	25	(101)
Al <sub>2</sub> (SO <sub>4</sub> ) <sub>3</sub> .....	Na <sub>2</sub> SO <sub>4</sub>	25	(43)
	K <sub>2</sub> SO <sub>4</sub>	25	(43)
MgCl <sub>2</sub> .....	NaNO <sub>3</sub>	20	(59)
Mg(NO <sub>3</sub> ) <sub>2</sub> .....	NaCl	20	(59)
	KNO <sub>3</sub>	20	(59)
CaCl <sub>2</sub> .....	NaCl	20	(59)
	NaNO <sub>3</sub>	20	(59)
Ca(NO <sub>3</sub> ) <sub>2</sub> .....	NaNO <sub>3</sub>	20	(59)
SrCl <sub>2</sub> .....	NaCl	20	(59)
	KNO <sub>3</sub>	20	(59)
Sr(NO <sub>3</sub> ) <sub>2</sub> .....	NaNO <sub>3</sub>	20	(59)
		25	(43)
	KCl	20	(59)
	KNO <sub>3</sub>	20	(59)
		25	(43)
BaCl <sub>2</sub> .....	Ba(NO <sub>3</sub> ) <sub>2</sub>	25	(43)
	NaCl	15	(12)
		20	(12, 59)
		25	(43)
	KCl	25	(43)
Ba(NO <sub>3</sub> ) <sub>2</sub> .....	NaNO <sub>3</sub>	25	(43)
	KNO <sub>3</sub>	25	(43)
NaOH.....	KOH	25	(43)
NaCl.....	NaNO <sub>3</sub>	25	(43)
	KCl	15	(12)
		20	(12)
		25	(43, 69, 85)
NaI.....	KI	25	(85)
Na <sub>2</sub> SO <sub>4</sub> .....	K <sub>2</sub> SO <sub>4</sub>	25	(43)
NaNO <sub>3</sub> .....	KNO <sub>3</sub>	25	(43)
Na <sub>2</sub> CO <sub>3</sub> .....	K <sub>2</sub> CO <sub>3</sub>	25	(43)
Na <sub>2</sub> SiO <sub>3</sub> .....	Na <sub>2</sub> WO <sub>4</sub>	30	(51)
KCl.....	KNO <sub>3</sub>	25	(43)
K <sub>2</sub> SO <sub>4</sub> .....	K <sub>2</sub> Cr <sub>2</sub> O <sub>7</sub>	25	(43)

 For solutions containing NH<sub>4</sub>OH and various salts, v. (4, 5, 43).

## AQUEOUS SOLUTIONS CONTAINING THREE OR MORE STRONG ELECTROLYTES

		Lit.
HCl + NaCl + KCl.....	25°	(69)
MgCl <sub>2</sub> + CaCl <sub>2</sub> + SrCl <sub>2</sub> + NaNO <sub>3</sub> .....	20°	(59)
MgCl <sub>2</sub> + Sr(NO <sub>3</sub> ) <sub>2</sub> + Ba(NO <sub>3</sub> ) <sub>2</sub> .....	20°	(59)
Mg(NO <sub>3</sub> ) <sub>2</sub> + Ca(NO <sub>3</sub> ) <sub>2</sub> + NaCl.....	20°	(59)
Mg(NO <sub>3</sub> ) <sub>2</sub> + Sr(NO <sub>3</sub> ) <sub>2</sub> + KCl + KNO <sub>3</sub> .....	20°	(59)
Mg(NO <sub>3</sub> ) <sub>2</sub> + SrCl <sub>2</sub> + NaCl + KNO <sub>3</sub> .....	20°	(59)

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VISCOSITY OF AQUEOUS SOLUTIONS OF WEAK ELECTROLYTES AND OF ALL ORGANIC ACIDS AND BASES

M. P. APPLEBEY

$F$  = Gram-formula-weight,  $\eta$  = Viscosity,  $\eta_w$  = Viscosity relative to water at the same temperature.\*

Weak Bases

$\text{NH}_3$	$F/l$	1	2	4	6	8	Lit.
25°	$\eta/\eta_w \pm 0.5\%$	1.020	1.040	1.081	1.121	1.169	(3)

AMINES

Values of  $\eta/\eta_w \pm 0.005$  at 25° C (24)

$F/l$	0.125	0.25	0.5	1.0
$\text{NH}_3$ (for comparison).....	1.003	1.006	1.0105	1.0245
$\text{CH}_3\text{NH}_2$ .....	1.017	1.034	1.082	1.155
$(\text{CH}_3)_2\text{NH}$ .....	1.030	1.063	1.144	1.304
$(\text{CH}_3)_3\text{N}$ .....	1.068	1.143	1.299	1.684
$(\text{CH}_3)_4\text{NOH}$ .....	1.035	1.072	1.146	1.316

$\text{C}_5\text{H}_5\text{N}$ , PYRIDINE (4, 14, 15, 19, 21, 26)

Values of  $\eta/\eta_w \pm 0.3\%$  at 0 and 25°;  $\pm 1\%$  at 18°;  $\pm >1\%$  at higher temperatures. Maxima at 63% for 0° and 66% for 25°

$t, ^\circ\text{C}$	Wt. %	20	40	60	80	100
0		1.790	2.560	3.120	2.410	0.745
18		1.580	2.375	2.570	2.155	0.925
25		1.530	2.065	2.475	2.140	0.995
55		1.39	1.74	2.02	1.96	1.18
77		1.25	1.55	1.82	1.83	1.35
100		1.20	1.43	1.69	1.83	1.41

Amino Acids (22)

Values of  $\eta/\eta_w \pm >0.002$

Formula	Name	$F/l$	$t, ^\circ\text{C}$	0.25	0.5	1.0	2.0
$\text{CH}_2\text{NH}_2\text{COOH}$	Glycocoll	18			1.070	1.153	1.362
		40			1.074	1.165	
$\text{CH}_3\text{CH}(\text{NH}_2)\text{COOH}$	Alanine	18	1.059	1.133	1.310		
		40		1.127	1.281		
$\text{C}_6\text{H}_5\text{CH}_2\text{CH}(\text{NH}_2)\text{COOH}$	Phenylalanine	18	8.31 g/l.	$\eta/\eta_w = 1.027$			

Monocarboxylic Acids

$\text{CO}_2$ , CARBON DIOXIDE (30)

$\eta/\eta_w$  for the saturated solution at 20° = 1.007.

$\text{HCO}_2\text{H}$ , FORMIC ACID (2, 5, 11, 17, 18, 27, 31, 36, 38)

Values of  $\eta$  in millipoises†

$t, ^\circ\text{C}$	Wt. %	20	40	60	80	90	100
15		12.75	13.90	15.60	17.95	19.20	19.85
20		11.10	12.50	14.10	16.10	17.10	17.90
25		10.10	11.30	12.85	14.65	15.55	16.05
35		8.25	9.35	10.70	12.20	12.95	13.35
45		6.90	7.85	9.05	10.30	10.85	11.25
55		5.85	6.76	7.75	8.80	9.30	9.60
65		5.10	5.70	6.75	7.70		
75		4.45	5.15	5.95	6.80		
85		3.90	4.55	5.25	6.05		

$F/l$	0.1	0.25	0.5	1.0	Lit.
$\eta/\eta_w, 25^\circ$	1.004	1.009	1.017	1.031	(31)

\* All interconversions between  $\eta$  and  $\eta/\eta_w$  have been based upon the values for water given on p. 10.

†  $\pm$  ca. 1% at 25°;  $> 1\%$  at higher temperatures.

$\text{CH}_3\text{CO}_2\text{H}$ , ACETIC ACID (2, 32, 34, 40)

Values of  $\eta$  in millipoises,  $\pm 0.5\%$  for low, and  $\pm (2-3)\%$  for high concentrations and temperatures

$t, ^\circ\text{C}$	Wt. %	10	20	30	40	50	60	70	75	90	100
15		13.60	16.30	19.10	21.60	24.75	27.65	30.20	31.05	26.80	13.50
20		12.10	14.15	16.35	18.70	21.35	23.90	26.40	26.95	23.10	12.65
25		10.65	12.50	14.50	16.55	18.70	20.85	22.90	23.65	20.50	11.55
30		9.55	11.10	12.90	14.75	16.60	18.50	20.40	20.95	18.40	10.65
35		8.55	10.00	11.50	13.15	14.80	16.50	18.15	18.55	16.55	9.90
40		7.80	9.05	10.40	11.80	13.25	14.70	16.20	16.60	14.90	9.25
45		7.10	8.20	9.40	10.60	11.85	13.20	14.45	14.85	13.45	8.65
50		6.50	7.45	8.55	9.65	10.80	11.90	13.05	13.40	12.25	8.10
55		6.00	6.80	7.75	8.80	9.85	10.80	11.95	12.15	11.25	7.60
60		5.50	6.25	7.10	8.00	9.00	9.95	10.90	11.05	10.30	7.00
65		5.05	5.75	6.55	7.35	8.20	9.00		10.10		6.75
75		4.40	4.95	5.60	6.30	7.00	7.65		8.55		6.05
85		3.85	4.35	4.90	5.45	6.05	6.60		7.40		5.45
95		3.40	3.85	4.30	4.75	5.30	5.75		6.40		4.90

$\eta/\eta_w, 25^\circ = [1 + 0.1104 F/l + 0.00208 (F/l)^2] \pm 0.002$  up to  $\eta/\eta_w, 18^\circ = [1 + 0.1169 F/l + 0.0013 (F/l)^2] \pm >0.002$  3N.

$\text{ClCH}_2\text{CO}_2\text{H}$ , MONOCHLOROACETIC ACID (7)

$F/l$ .....	0.1	0.25	0.5	1.0	2.0	3.0	3.84
$\eta/\eta_w, 25^\circ$ .....	1.018	1.045	1.088	1.161	1.330	1.536	1.717 $\pm 0.002$

$\text{Cl}_2\text{CHCO}_2\text{H}$ , DICHLOROACETIC ACID (24)

$F/l$ .....	0.1	0.25	0.5	1.0
$\eta/\eta_w, 25^\circ$ .....	1.024	1.064	1.131	1.265 $\pm 0.005$

$\text{Cl}_3\text{CCO}_2\text{H}$ , TRICHLOROACETIC ACID (6)

$\eta/\eta_w, 25^\circ = (1 + 0.355n) \pm 0.002$ , up to  $n = \frac{1}{2}$  normal.

$\text{CH}_3\text{CHClCCl}_2\text{CO}_2\text{H}$ , TRICHLOROBUTYRIC ACID (6)

$\eta/\eta_w, 25^\circ = (1 + 0.435n) \pm 0.002$  up to  $n = 0.2N$ .

$\text{CH}_3\text{CH}_2\text{CO}_2\text{H}$ , PROPIONIC ACID

$F/l$ .....	0.1	0.25	0.5	1.0	1.5	2.0
$\eta/\eta_w$ { 18°	1.019	1.048	1.096	1.191	1.291	1.392
25°	1.019	1.048	1.098	1.098	1.310	1.430
						$\pm 0.002$ } (31, 40)

$\eta$  in millipoises ( $\pm 2\%$  at 20°)

$t, ^\circ\text{C}$	Wt. %	10	30	50	70	90	100	Lit.
20		12.95	18.65	24.0	28.05	26.4	11.2	(38)
40		8.6	11.9	15.5			9.0	(37)
60		6.2	8.4	10.35			7.35	(37)

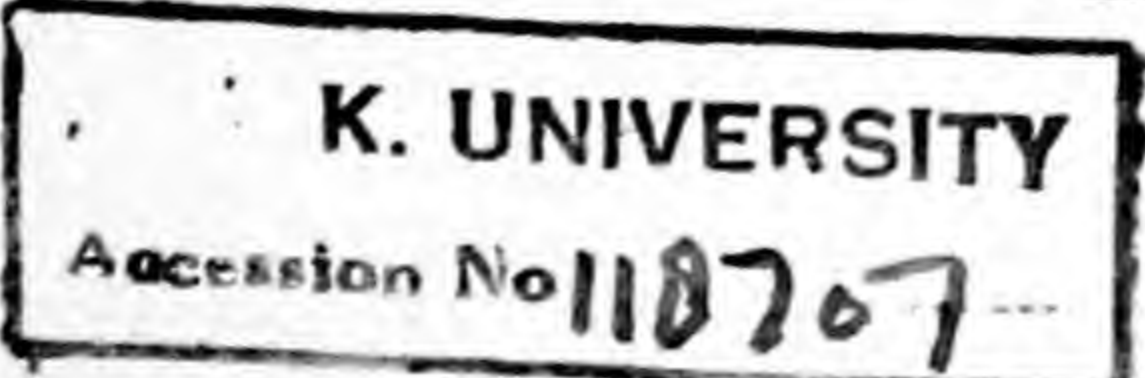
$\text{C}_4\text{H}_9\text{O}_2$ , BUTYRIC ACID

$F/l$ .....	0.1	0.25	0.5	1.0	(31, 40)
$\eta/\eta_w, 25^\circ$ { $n$ .....	1.025	1.063	1.131	1.280	$\pm 0.002$
iso.....	1.026	1.066	1.129	1.273	$\pm 0.003$

$\text{CH}_3\text{CH}_2\text{CH}_2\text{CO}_2\text{H}$ , *n*-BUTYRIC ACID

$\eta$  in millipoises,  $\pm$  several %, max. at ca. 72% for 20°

$t, ^\circ\text{C}$	Wt. %	10	30	50	75	100	Lit.
20		13.6	22.3	31.3	36.0	16.0	(37, 38)
40		8.5	13.3	17.9		11.8	(37)
60		6.3	9.0	12.0		9.1	(37)





(CH<sub>3</sub>)<sub>2</sub>CHCO<sub>2</sub>H, ISOBUTYRIC ACID

 $\eta/\eta_w \pm 0.5\%$  (16)

Wt. %	10	20	30	40	50	60	100
20	1.340	1.765	Two liquid phases				1.305
25	1.320	1.725					1.355
30		1.685	2.210	2.720	2.990	3.120	1.400
35		1.660	2.130	2.590	2.890	3.030	1.445
40		1.625	2.065	2.480	2.780	2.945	1.485

 CH<sub>3</sub>CH(OH)CO<sub>2</sub>H, LACTIC ACID (10, 31)

$\frac{1}{2}F/l$ .....	0.1	0.25	0.5	1.0	
$\eta/\eta_w$ , 25°, $\pm 0.003$	1.0255	1.0585	1.119	1.250	
Wt. %.....	10	30	50	70	100
$\eta/\eta_w$ , 25°, $\pm 0.1\%$	1.270	2.020	3.67	7.2	45.3

 (CH<sub>3</sub>)<sub>2</sub>CHCH<sub>2</sub>CO<sub>2</sub>H, ISOVALERIC ACID (31)

 $\eta/\eta_w$ , 25° = (1 + 0.300n)  $\pm$  0.003; up to n = 0.25N.

 C<sub>6</sub>H<sub>5</sub>CH(OH)CO<sub>2</sub>H d-, l-, or dl-MANDELIC ACID (13)

Wt. % . . . . .	2	4	6	8	10	
$\eta/\eta_w$ , 25° . . . . .	1.047	1.106	1.171	1.240	1.315	$\pm 0.002$

## Dicarboxylic Acids

 HO<sub>2</sub>CCO<sub>2</sub>H, OXALIC ACID

$F/l$ .....	0.1	0.25	0.5	1.0		(23, 38)
$\eta/\eta_w$ , 18°.....	1.018	1.045	1.090	1.200	$\pm 0.003$	

 HO<sub>2</sub>CCH<sub>2</sub>CH<sub>2</sub>CO<sub>2</sub>H, SUCCINIC ACID (23)

$\frac{1}{2}F/l$ .....	0.1	0.25	0.5	1.0		
$\eta/\eta_w$ { 18°	1.010	1.026	1.052	1.109	$\pm 0.005$	(28, 33)
25°	1.012	1.029	1.058	1.117		

 HO<sub>2</sub>CCH(OH)CH(OH)CO<sub>2</sub>H, TARTARIC ACID (28)

$F/l$ .....	0.1	0.25	0.5	1.0	1.5	
$\eta/\eta_w$ , 18°.....	1.029	1.072	1.153	1.400	1.712	$\pm 0.004$

 At 25°,  $\eta/\eta_w$  for a 13.04 Wt. % solution = 1.401 for the d- and 1.388 for the dl-acid (13).

 HO<sub>2</sub>CCH(CH<sub>3</sub>)CH<sub>2</sub>CO<sub>2</sub>H, METHYLSUCCINIC ACID (33)

$\frac{1}{2}F/l$ .....	0.1	0.25	0.5		
$\eta/\eta_w$ , 25°.....	1.0145	1.037	1.078	$\pm 0.002$	

 CH<sub>2</sub>:C(CO<sub>2</sub>H)CH<sub>2</sub>CO<sub>2</sub>H, ITACONIC ACID (33)

 $\eta/\eta_w$ , 25° = (1 + 0.143n)  $\pm$  0.001 up to n = 0.34N.

 HO<sub>2</sub>CCH(OCOCH<sub>3</sub>)CH(OCOCH<sub>3</sub>)CO<sub>2</sub>H, DIACETYLTARTARIC ACID (8)

$\frac{1}{2}F/l$ .....	0.1	0.25	0.5	1.0	
$\eta/\eta_w$ , 25°.....	1.026	1.067	1.142	1.308	$\pm 0.003$

## Sulfonic Acids and Phenol

 CH<sub>3</sub>C<sub>6</sub>H<sub>4</sub>SO<sub>3</sub>H, p-TOLUENESULFONIC ACID (6)

 $\eta/\eta_w$ , 25° = (1 + 0.435n)  $\pm$  0.02 up to n = 0.2N.

 (CH<sub>3</sub>)<sub>3</sub>C<sub>6</sub>H(NH<sub>2</sub>)SO<sub>3</sub>H, TRIMETHYLSULFANILIC ACID (25)

 $\eta/\eta_w$ , 25° = (1 + 0.0148  $\times$  Wt. %) up to 2% acid.

 C<sub>6</sub>H<sub>5</sub>OH, PHENOL

$F/kg$ soln.....	0.1	0.25	0.5	(20)
$\eta/\eta_w$ , 18°.....	1.019	1.049	1.101	$\pm 0.004$

 $\eta/\eta_w \pm 0.5\%$  up to 80°; less accurate above 80° (1, 16, 35)

Wt. %	10	20	35	50	65	80	100
50	1.195	Two liquid phases				3.065	6.39
60	1.185					2.855	5.64
67.5	1.175	1.475	2.135	2.560	2.745	3.275	5.16
75	1.170	1.455	1.945	2.365	2.640	3.160	4.78
80	1.170	1.420	1.880	2.285	2.575	3.085	4.59
85	1.165	1.400	1.855	2.200	2.550	3.010	
90		1.385		2.180			
95		1.355		2.125			

## SYSTEMS WITH TWO SOLUTES

Water—acetic acid—toluene (41).

Water—methyl or ethyl alcohol—picric acid (19.1).

Water—methyl or ethyl alcohol—aniline (19.1).

Water—methyl or ethyl alcohol—toluidine (19.1).

Water—methyl or ethyl alcohol—piperidine (19.1).

## LITERATURE

(For key to the periodicals see end of volume)

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## VISCOSITY OF AQUEOUS SOLUTIONS OF NON-ELECTROLYTES

GUY BARR

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## ABBREVIATIONS

F = Gram-formula-weight

 $\eta$  = Viscosity

 $\eta/\eta_w$  = Viscosity relative to water at the same temperature.\*

 \* All interconversions between  $\eta$  and  $\eta/\eta_w$  have been based upon the values for water given on p. 10.

## INTRODUCTION

Throughout this section where a table is given under the name of one author only, it may be assumed, unless the contrary is stated:

1. That a viscometer of the Ostwald type was used for the determinations, no mention having been made by the experimenter of a test for the compliance of his instrument with Poiseuille's law, and no kinetic energy correction having been applied to the results. The abbreviation (K. E.) indicates that a kinetic energy correction has been applied.

 2. That the mixtures were made up by weight without reduction *ad vacuum*.

In the majority of cases the purity of the solute is of prime importance in determining the viscosity of the solutions; melting



points, boiling points, etc., are therefore quoted where such details are given. The viscosities tabulated for the pure liquid non-electrolytes may be found to differ from the I. C. T. values for the pure liquids, but it is not possible, in general, to adjust the tables to remove the discrepancy.

### Systems Containing But One Solute

C-Arrangement (v. Vol. III, p. viii)

CH<sub>3</sub>NO, FORMAMIDE, HCONH<sub>2</sub>

$\eta$  in millipoises (11, 30, 44)

Wt. %	0.0	20.0	40	60	80	100
$\eta_{25}$	8.9	10.0	11.6	14.6	20.7	32.7

CH<sub>3</sub>O, METHYL ALCOHOL, CH<sub>3</sub>OH  
(B. P., 64.9°C);  $\eta$  in millipoises (K. E.) (5)

Wt. %	$t, ^\circ\text{C}$	25	35	45	55
21.41		14.23	10.89	8.58	7.02
47.36		15.61	11.99	9.47	7.74
71.61		11.89	9.57	7.80	6.52
100.00		5.48	4.76	4.17	3.71

### SPECIALLY DRIED ALCOHOL

$\eta$  in millipoises (42)

Wt. %	84.86	88.79	91.90	95.35	97.52	98.77	99.24	100.0
$\eta_{15}$	11.20	10.03	8.98	7.88	7.14	6.76	6.57	6.34

CH<sub>4</sub>N<sub>2</sub>O, UREA, CO(NH<sub>2</sub>)<sub>2</sub> (33)

F/l.	0.25	0.5	1.0	2.0	4.0	8.0
$\eta/\eta_w, 20^\circ$	1.010	1.022	1.039	1.088	1.215	1.655

(M. P., 132°C);  $\eta$  in millipoises (11)

Wt. %	1.02	8.13	11.89	15.47	23.12	33.28	38.13	46.18
$\eta_{25}$	8.99	9.43	9.73	10.40	10.93	12.57	13.54	15.68

C<sub>2</sub>HCl<sub>3</sub>O, CHLORAL, Cl<sub>3</sub>CCHO

Solutions up to 50M % made from the hydrate ( $d_4^{20} = 1.6193$ ); above 50M % from chloral (B. P., 97.0–97.2°C), ( $d_4^{25} = 1.5049$ ) (27)

Mole % C <sub>2</sub> HCl <sub>3</sub> O	$\eta$ in millipoises				
	50°	60°	70°	85°	90°
0.0	5.49	4.70	4.07	3.36	3.17
2.0		5.95		4.20	
5.0	10.33	8.41	6.87	5.50	4.75
10.0	17.35	13.97	10.80	8.41	7.39
15.0	26.77	20.97	16.25	11.80	10.27
20.0	41.65	31.00	22.84	16.17	13.65
25.0	60.00	43.58	30.04	20.34	16.97
30.0	87.70	57.79	37.62	23.96	19.67
35.0	113.86	72.39	45.39	27.06	21.77
40.0	143.57	85.74	50.80	28.52	22.56
42.5	156.07	90.50	51.63	29.02	22.35
45.0	164.06	91.72	51.51	28.43	21.44
46.5	170.98	90.91	50.65	27.47	21.05
47.5	174.21	90.17	50.27	26.59	20.61
49.0	172.99	88.19	48.66	25.58	
50.0	167.55	86.82	47.86	24.81	19.61
55.0	141.04	75.79	40.72	21.70	
60.0	114.17	60.45	34.04	18.79	
70.0	57.07	34.07	21.60	13.11	
80.0	26.87	18.52	13.57	9.04	
90.0	14.50	11.55	9.73	6.56	
100.0	8.71	7.82	6.79	5.58	5.24

C<sub>2</sub>H<sub>5</sub>NO, ACETAMIDE, CH<sub>3</sub>CONH<sub>2</sub>

M. P., 82°C;  $\eta$  in millipoises (11)

Wt. %	0	0.78	5.82	17.69	25.95	37.21	69.26
$\eta_{25}$	8.95	8.94	9.95	12.38	14.65	18.83	44.62

### C<sub>2</sub>H<sub>5</sub>NO.—(Continued)

Values of  $\eta/\eta_w$  (43)

$t, ^\circ\text{C}$	5	10	15	20	25	30	35	40
0.1	1.089	0.957	0.982	0.996	1.000	1.001	0.985	0.988
0.25	1.161	0.985	1.020	1.013	1.045	1.017	1.012	1.001
0.5	1.179	1.053	1.028	1.027	1.063	1.044	1.025	1.052
0.75	1.293	1.095	1.081	1.069	1.074	1.092	1.043	1.065
1.0	1.344	1.133	1.133	1.103	1.126	1.157	1.128	1.085

C<sub>2</sub>H<sub>5</sub>O, ETHYL ALCOHOL, C<sub>2</sub>H<sub>5</sub>OH (5, 12)

Values of  $\eta$  in millipoises  $\pm 0.2\%$  between 20 and 60°C. Solutions near  $\eta_{\text{max}}$  may be used for calibration of viscometers if evaporation is avoided.

Wt. %	$t, ^\circ\text{C}$	0	10	20	25	30	40	50	60	70
10		32.15	21.62	15.48	13.28	11.53	8.96	7.25	6.02	5.09
20		52.75	32.35	21.68	18.08	15.39	11.44	8.96	7.28	6.06
30		69.0	40.95	26.70	22.03	18.49	13.53	10.38	8.26	6.77
40		71.5	43.55	28.67	23.74	19.91	14.55	11.16	8.87	7.24
45		70.1	43.1	28.67	23.87	20.07	14.78	11.38	9.02	7.36
50		66.25	41.74	28.32	23.68	20.01	14.75	11.36	9.04	7.39
60		57.15	37.87	26.42	22.32	19.06	14.26	11.09	8.87	7.27
70		47.2	32.68	23.69	20.25	17.44	13.28	10.44	8.41	6.96
80		36.48	26.63	19.98	17.38	15.19	11.81	9.50	7.78	6.48
90		26.94	20.48	16.01	14.22	12.70	10.22	8.35	6.95	5.89
100		17.76	14.80	12.21	11.01	9.97	8.24	6.95	5.90	5.06

C<sub>2</sub>H<sub>6</sub>O<sub>2</sub>, GLYCOL, (HOCH<sub>2</sub>)<sub>2</sub>

( $d_4^{25} = 1.1110$ );  $\eta$  in millipoises (10)

Wt. %	$\eta_{25}$	Wt. %	$\eta_{25}$	Wt. %	$\eta_{25}$
0.00	8.95	45.13	28.73	69.52	62.54
14.11	12.64	49.55	32.13	75.64	92.42
33.11	16.28	60.84	45.08	100.00	180.9

C<sub>3</sub>H<sub>6</sub>O, ALLYL ALCOHOL, CH<sub>2</sub>:CHCH<sub>2</sub>OH

( $d_4^{25} = 0.8500$ );  $\eta$  in millipoises (10)

Wt. %	0.00	14.06	25.98	33.70	35.53	36.53	45.21	46.88
$\eta_{25}$	8.95	13.55	16.89	17.97	18.42	18.54	18.96	19.03
Wt. %	47.31	47.82	48.56	56.63	65.00	69.56	83.20	100.00
$\eta_{25}$	18.95	18.99	19.00	18.99	18.04	17.58	15.44	12.37

C<sub>3</sub>H<sub>6</sub>O, ACETONE, (CH<sub>3</sub>)<sub>2</sub>CO

(B. P., 56.1°C);  $\eta$  in millipoises (K. E.) (3, 31)

Wt. %	0.0	12.2	14.4	23.6	24.7	30.3	40.7
$\eta_{25}$	8.95	11.39	11.82	13.15	13.24	13.60	13.43
Wt. %	50.6	61.2	70.9	80.4	89.9	100.0	
$\eta_{25}$	12.30	10.25	8.10	6.06	4.37	3.17	
Wt. %	0.0	0.41	0.66	1.81	3.29	9.12	16.76
$\eta_{20}$	10.09	10.18	10.26	10.57	10.95	12.55	13.70

$\eta$  in millipoises  $\pm ca. 0.5\%$ ; Vol. % at 18–20°C (7, 22)

Vol. %	$t, ^\circ\text{C}$	0	15	25	35	45
0		17.94*	11.45	8.95	7.21	5.97
12.5			14.45	10.90	8.55	6.96
25		29.6*	17.20	12.76	9.81	7.83
37.5			18.43	13.68	10.37	8.26
50		30.6*	17.88	13.35	10.26	8.18
62.5			15.29	11.82	9.13	7.38
75		17.2*	11.26	8.94	7.26	6.02
100		4.1*		3.24*		

\* Values marked with \* are from (22).



**C<sub>3</sub>H<sub>7</sub>NO, PROPIONAMIDE, C<sub>3</sub>H<sub>5</sub>CONH<sub>2</sub>**  
(M. P., 80–81°C);  $\eta$  in millipoises (11)

Wt. %	0.00	1.24	5.65	11.71	22.18	41.48	70.65
$\eta_{25}$	8.95	9.23	10.30	11.93	15.43	30.43	60.06

**C<sub>3</sub>H<sub>8</sub>O, *n*-PROPYL ALCOHOL, C<sub>3</sub>H<sub>7</sub>OH**  
(B. P., 97.7°C);  $\eta$  in millipoises (12)

$t, ^\circ\text{C}$	Wt. %	0.00	17.40	28.62	59.38	73.13	100.00
20		10.09	20.23	25.65	31.69	29.58	21.95
25		8.95	17.04	21.27	26.64	25.20	19.44
30		8.00	14.45	18.18	23.14	21.76	17.42

**C<sub>3</sub>H<sub>8</sub>O<sub>3</sub>, GLYCEROL, C<sub>3</sub>H<sub>5</sub>(OH)<sub>3</sub>**  
 $\eta$  in millipoises (K. E.); values of  $d$  in vacuo (1)

$d_{20}^{20}$	$\eta_{20}$	$d_{20}^{20}$	$\eta_{20}$	$d_{20}^{20}$	$\eta_{20}$
1.0000	10.09	1.1848	235.4	1.2240	1108
1.1014	37.34	1.2057	496.7	1.2463	4093
1.1699	153.6	1.2155	747.8	1.2568	8717

$\eta$  relative to that of 99.5% glycerol at 25°C (39); commercial samples of double-distilled glycerol diluted to  $d_4^{25} = 1.252$  may, however, differ in  $\eta$  by as much as 8% (2, 25).

$d_4^{25}$	1.2539	1.2526	1.2520	1.2510	1.2500	1.2480
$10 \eta/\eta_0^{25}$	10.87	10.00	9.61	8.99	8.40	7.30
$d_4^{25}$	1.2460	1.2440	1.2420	1.2400	1.2370	1.2340
$10 \eta/\eta_0^{25}$	6.35	5.52	4.84	4.26	3.57	3.00

**C<sub>4</sub>H<sub>9</sub>NO, *n*-BUTYRAMIDE, C<sub>3</sub>H<sub>7</sub>CONH<sub>2</sub>**  
(M. P., 116°C);  $\eta$  in millipoises (11)

Wt. %	0.00	1.02	8.11	16.88	17.92
$\eta_{25}$	8.95	9.10	11.27	14.64	15.18

**C<sub>6</sub>H<sub>6</sub>O<sub>2</sub>, HYDROQUINOL, *p*-C<sub>6</sub>H<sub>4</sub>(OH)<sub>2</sub> (28)**

Wt. %	$\eta/\eta_{25}$	Wt. %	$\eta/\eta_{25}$	Wt. %	$\eta/\eta_{25}$	Wt. %	$\eta/\eta_{25}$
0.10	1.171	0.75	1.172	2.00	1.234	4.00	1.275
0.25	1.161	1.00	1.206	3.00	1.271	5.00	1.295
0.50	1.167	Scarpa viscometer, $t = 2t_1t_2/(t_1 + t_2)$					

**C<sub>6</sub>H<sub>6</sub>O<sub>2</sub>, PYROCATECHOL, *o*-C<sub>6</sub>H<sub>4</sub>(OH)<sub>2</sub> (28)**

Wt. %	$\eta/\eta_{25}$	Wt. %	$\eta/\eta_{25}$	Wt. %	$\eta/\eta_{25}$	Wt. %	$\eta/\eta_{25}$
0.10	1.132	0.75	1.132	2.00	1.259	4.00	1.263
0.25	1.113	1.00	1.204	3.00	1.238	5.00	1.251
0.50	1.126	Scarpa viscometer, $t = 2t_1t_2/(t_1 + t_2)$					

**C<sub>6</sub>H<sub>12</sub>O<sub>6</sub>, DEXTROSE**

Wt. %	$\eta$ in millipoises (37)					
<i>in vacuo</i>	25°	30°	35°	40°	45°	50°
9.67	11.70	10.38	9.24	8.34	7.52	6.89
18.66	15.86	13.91	12.27	10.89	9.76	8.84
27.08	22.31	19.49	17.00	15.03	13.30	11.93
34.94	33.3	28.80	24.73	21.64	18.98	16.90
42.33	52.4	44.0	37.4	32.2	27.80	24.35
49.33	88.2	72.2	60.2	50.9	42.8	36.9

$\eta/\eta_0$  (43)

$F/l$	5°	10°	15°	20°	25°	30°	35°	40°
0.1	1.212	1.024	1.048	1.027	1.047	1.049	1.013	1.020
0.25	1.363	1.210	1.197	1.186	1.198	1.199	1.169	1.167
0.5	1.450	1.329	1.266	1.289	1.324	1.294	1.237	1.188
0.75	1.739	1.526	1.476	1.447	1.447	1.464	1.411	1.414
1.0	1.889	1.637	1.611	1.621	1.588	1.597	1.528	1.514

Shelton (45) gives  $\eta$  for confectioner's glucose syrup (Corn Products Refining Company) and for mixtures of this with water and pure dextrose:

**C<sub>6</sub>H<sub>12</sub>O<sub>6</sub>—(Continued)**

Solution ( $\eta$ in poises)	$d_4^{25}$	$\eta_{25}$
1. Original syrup + dextrose	1.470	165000
2. Original syrup + dextrose	1.447	14000
3. Original syrup	1.436	5000
4. Original syrup + H <sub>2</sub> O	1.420	764
5. Original syrup + H <sub>2</sub> O	1.379	36.6
6. Original syrup + H <sub>2</sub> O	1.331	3.7

**C<sub>6</sub>H<sub>12</sub>O<sub>6</sub>, GALACTOSE;  $\eta$  in millipoises (38)**

Wt. %	0.00	1.15	2.30	4.60	9.12	18.24
$\eta_{25}$	8.95	9.22	9.50	10.06	11.48	15.64

Honey (41).

**C<sub>6</sub>H<sub>12</sub>O<sub>6</sub>, LEVULOSE;  $\eta$  in millipoises (37)**

$t, ^\circ\text{C}$	Wt. %	0.00	9.58	18.49	26.96	34.81	42.18	49.07
20		10.09	13.06	17.63	24.44	36.06	56.25	95.6
25		8.95	11.40	15.33	21.04	30.3	46.7	77.2
30		8.00	10.19	13.52	18.37	25.97	39.1	63.5
35		7.21	9.08	11.88	16.15	22.45	33.25	52.8

**C<sub>12</sub>H<sub>22</sub>O<sub>11</sub>, LACTOSE;  $\eta$  in millipoises (38)**

Wt. %	0.00	1.28	2.78	5.80	11.66	17.06	23.38
$\eta_{25}$	8.95	9.28	9.72	10.61	12.97	15.91	21.21

**C<sub>12</sub>H<sub>22</sub>O<sub>11</sub>, MALTOSE;  $\eta$  in millipoises (38)**

Wt. %	0.00	1.16	2.32	4.77	9.60	19.40
$\eta_{25}$	8.95	9.31	9.66	10.35	12.26	18.12

**C<sub>12</sub>H<sub>22</sub>O<sub>11</sub>, SUCROSE**

$\eta$  in millipoises (K. E.). Wt. % in vacuo; solutions suitable for standardization of viscometers (4)

$t, ^\circ\text{C}$	Wt. %	20	40	60	$t, ^\circ\text{C}$	Wt. %	20	40	60
0		38.18	148.2		50		9.74	25.06	140.6
5		31.66	116.0		55		8.87	22.27	117.1
10		26.62	98.30	1139	60		8.11	19.89	98.7
15		22.75	74.96	749	65		7.45	17.85	83.7
20		19.67	62.23	567	70		6.88	16.14	71.8
25		17.10	52.06	440.2	75		6.37	14.67	62.2
30		15.10	43.98	340.1	80		5.92	13.39	54.2
35		13.36	37.76	266.2	85		5.52	12.26	47.5
40		11.97	32.61	213.0	90			11.27	41.7
45		10.74	28.58	172.4	95			10.41	37.3

Supersaturated solutions:  $\eta$  in poises  $\pm 2\%$  (K. E.) (35). (The non-sucrose present in crude beet-sugar is equivalent, on the average, to ca. 0.97 of its weight of sucrose in solutions of the concentrations below. But a solution of a crude sugar (90% purity) gave a viscosity only 0.8 of that of a pure sucrose solution of the same density, 1.314 at 19°C).

Wt. %	$\eta_{20}$	$\eta_{30}$	Wt. %	$\eta_{20}$	$\eta_{30}$
60	0.57	0.34	70	4.47	1.97
65	1.35	0.78	75		9.6

**C<sub>18</sub>H<sub>32</sub>O<sub>16.5</sub>H<sub>2</sub>O, RAFFINOSE**

(0.1 formal soln. had specific conductance of  $< 2 \times 10^{-6}$  mhos at 25°C); fused quartz viscometer (K. E.);  $F/l$  in vacuo (46)

0.00°C		25.00°C		50.00°C	
$F/l$ at 0°	$\eta/\eta_w$	$F/l$ at 25°	$\eta/\eta_w$	$F/l$ at 50°	$\eta/\eta_w$
0.038083	1.06284	0.037973	1.05602	0.037615	1.04723
0.058632	1.10129	0.058466	1.08809	0.057925	1.07780
0.102676	1.18881	0.102297	1.16262	0.129787	1.19272
0.131202	1.25233	0.130727	1.21713	0.174336	1.27057
0.176625	1.36048	0.175818	1.31230		



## Systems Containing Two Solutes

C-Arrangement (v. Vol. III, p. viii)

CH<sub>3</sub>OH + C<sub>2</sub>H<sub>5</sub>OH, METHYL AND ETHYL ALCOHOLS $\eta$  in millipoises (K. E.) (5)

2CH <sub>3</sub> O.3H <sub>2</sub> O C <sub>2</sub> H <sub>5</sub> O.3H <sub>2</sub> O	Volumes...	0	25	50	75	100
		100	75	50	25	0
$\eta_{25}$ .....		23.5	21.1	18.8	16.8	14.7
$\eta_{35}$ .....		17.2	15.6	14.1	12.8	11.1
$\eta_{45}$ .....		13.0	12.0	11.0	10.1	9.2
$\eta_{55}$ .....		10.2	9.4	8.8	8.2	7.5

Mixture of 1 volume water with 20 volumes of a mixture of equal volumes of methyl and ethyl alcohols;  $\eta$  in millipoises (K. E.) (5)

$t, ^\circ\text{C}$ .....	25	35	45	55
$\eta$ .....	9.89	7.97	6.73	5.66

C<sub>2</sub>H<sub>5</sub>OH + C<sub>2</sub>H<sub>5</sub>(OH)<sub>2</sub>, ETHYL ALCOHOL AND GLYCEROL $N = 1F$  of glycerol per l of solution (34)

Liquid	$\eta/\eta_w, 20^\circ$
Water.....	1
50 % alcohol.....	2.807
$N$ Glycerol in water.....	1.275
$N$ Glycerol in 50 % alcohol.....	3.400
$N$ Glycerol in absolute alcohol.....	1.770

C<sub>2</sub>H<sub>5</sub>OH + C<sub>4</sub>H<sub>10</sub>O, ETHYL ALCOHOL AND ETHER $\eta_{15}$  (26);  $\eta_{25}$  (20)C<sub>2</sub>H<sub>5</sub>OH + C<sub>12</sub>H<sub>22</sub>O<sub>11</sub>, ETHYL ALCOHOL AND SUCROSE $\eta$  in millipoises (37)

	In 20 Wt. % alcohol		In 50 Wt. % alcohol			
Wt. % sucrose.....	0	20	0	10	20	30
$\eta_{25}$ .....	16.2	29.5	23.2	30.3	45.9	77.0

DEXTROSE + ACETAMIDE (43)

SUCROSE + DEXTROSE OR LEVULOSE

 $\eta$  in millipoises (37)

% sucrose....	20	20	20	20	10	5	0
% dextrose....	0	5	10	20	20	20	20
$\eta_{25}$ .....	16.8	21.0	26.5	47.5	26.0	20.1	16.8
% sucrose....	20	20	20	20	10	5	0
% levulose....	0	5	10	20	20	20	20
$\eta_{25}$ .....	16.8	21.4	26.2	45.2	25.3	19.8	16.2

Mixture containing 8.2 Wt. % each of sucrose, dextrose and levulose had  $\eta_{25} = 19.4$ .

## Systems Containing Two Solutes, One an Electrolyte and the Other a Non-Electrolyte

Alphabetical arrangement by non-electrolyte

ACETONE + CA(NO<sub>3</sub>)<sub>2</sub> (21)

ACETONE + CsCl (9)

ACETONE + CsNO<sub>3</sub> (9)

ACETONE + KCNS (23)

ACETONE + LiBr (22)

ACETONE + RbCl, RbBr, RbI or RbNO<sub>3</sub> (7)

DEXTROSE + HCl, KOH, OR TARTARIC ACID (43)

ETHER + H<sub>2</sub>SO<sub>4</sub> (36)ETHYL ALCOHOL + CA(NO<sub>3</sub>)<sub>2</sub> (32)ETHYL ALCOHOL + CsCl or CsNO<sub>3</sub> (9)

ETHYL ALCOHOL + HCl or HBr (16.5)

ETHYL ALCOHOL + KI (19, 47)

ETHYL ALCOHOL + KCNS (23)

ETHYL ALCOHOL + LiBr (22)

ETHYL ALCOHOL + NaI (16.5, 47)

ETHYL ALCOHOL + NH<sub>4</sub>Br (18)ETHYL ALCOHOL + NH<sub>4</sub>I (8, 18)GLYCEROL + CoCl<sub>2</sub> (40)GLYCEROL + CsCl or CsNO<sub>3</sub> (8)GLYCEROL + CuSO<sub>4</sub> (29)

GLYCEROL + KCl (18)

GLYCEROL + KI (40)

GLYCEROL + LiBr (40)

GLYCEROL + NaNO<sub>3</sub> (18)

GLYCEROL + RbBr (8)

GLYCEROL + RbI (18)

GLYCEROL + SrCl<sub>2</sub> (18)METHYL ALCOHOL + CsCl or CsNO<sub>3</sub> (9)

METHYL ALCOHOL + KCNS (23)

METHYL ALCOHOL + LiBr (22)

METHYL ALCOHOL + HCl, HBr or NaI (16.5)

SUCROSE + LiCl;  $\eta$  in millipoises (K. E.) (17)

Mole ratio, LiCl/C <sub>12</sub> H <sub>22</sub> O <sub>11</sub> =	0	0.05	0.50	5.0
Sucrose, F/l, 25°C	$\eta_{25}$	$\eta_{25}$	$\eta_{25}$	$\eta_{25}$
0.2	10.71	10.74	10.92	12.50
0.4	13.08	13.12	13.60	18.27
0.6	16.37	16.51	17.40	28.46
0.8	21.05	21.28	22.93	48.71
1.0	27.84	28.22	31.23	95.8
1.2	38.07	38.71	44.10	231.7
1.4	54.0	55.2	65.3	778
1.6	79.9	82.1	102.6	
1.8	124.8	130.0	172.7	
2.0	218	280	310	

UREA + HCl, KCl or NaOH (14)

## Cellulose in Cuprammonium Solutions

$\eta$  at 20°C of solutions of 20 g of cellulose in 1 l cuprammonium hydroxide solution containing 13 g copper and 200 g ammonia per l may vary between 28 000 poises (by extrapolation) and 0.4 poise according to the extent of degradation (Joyner) (24). The sliver used in Joyner's work gave  $\eta_{20} = 5000$  poises after boiling with water.

The Research Department, Woolwich (48) quotes figures of 216 poises for sliver and 74 poises for wood cellulose at 20°C, using a solution containing  $11 \pm 0.2$  g Cu,  $205 \pm 2$  g ammonia, and 20 g cellulose per liter.

Both the above workers confirm the conclusion of Gibson, Spencer and McCall (16) as to the rapid lowering of  $\eta$  on exposure to light or air.

Farrow and Neale (13) find that a carefully bleached cotton cloth should give  $\eta_{20} = 10$  to 300 poises when dissolved to a 2 % solution in cuprammonium solution containing 15 g Cu and 240 g ammonia per liter.

## EFFECT OF CU CONCENTRATION

Two per cent cellulose solutions;  $\eta$  in poises

Cu g/l.....	10	11.5	13	15	18	24	29.4	NH <sub>3</sub> , 210 g/l (24)
$\eta_{20}$ .....	266	163	129	101	81	58	53.5	
Cu g/l.....	9.5	10.4	10.9	11.7	NH <sub>3</sub> , 205 g/l (48)			
$\eta_{20}$ .....	150	137	130	121				

*Effect of Concentration of Ammonia.*—Joyner (24) finds that with any concentration of copper and with either 1 % or 2 % solutions of various celluloses, increase of ammonia by 10 g/l decreases  $\log_{10} \eta$  by 0.047.

*Effect of Concentration of Cellulose.*—Joyner states that for his solution  $\log \eta = \alpha C$ , where  $C$  = volume concentration and  $\alpha$  is a constant for a given cellulose. Farrow and Neale (13), using severely kivered sliver in their cuprammonium solution, find that the equation  $(1 + A/C) \log_{10} \eta/\eta_0 = B$  represents the results



more accurately, A and B being constants, and  $\eta_s$ , the viscosity of the solvent = 0.015 poise.

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## FLUIDITY OF NON-AQUEOUS SOLUTIONS

EUGENE C. BINGHAM

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Two-component systems.

Three-component systems.

The A-component has key-formula beginning with 16.

Two-component systems.

Three-component systems.

## INTRODUCTION

When the relation between specific volume and volume concentration is a linear one, the fluidity is normally a linear function of the volume concentration. Most of the literature from which the fluidity data are taken contains the corresponding density values, but these have not been reproduced here since such data are very fully given in another volume (*v. Vol. III*, p. 130). The accuracy is very difficult to estimate. Where data of different observers are available the agreement is in many cases not good. Differences of several per cent are not uncommon.

## MATIÈRES

La formule clé du constituant A ne commence pas par 16.

Systèmes à deux constituants.

Systèmes à trois constituants.

Le constituant A possède une formule clé commençant par 16.

Systèmes à deux constituants.

Systèmes à trois constituants.

## INTRODUCTION

Lorsque la relation entre le volume spécifique et la concentration en volume est linéaire, la fluidité est normalement une fonction linéaire de la concentration en volume. La plupart des mémoires dont ont été extraites les données de fluidité contiennent les valeurs des densités correspondantes, mais celles-ci n'ont pas été reproduites ici car de telles valeurs ont déjà été données d'une façon complète dans une autre volume (*v. Vol. III*, p. 130). Il est très difficile d'estimer la précision. Lorsque les données d'observateurs différents sont disponibles on constate que l'accord est mauvais dans bien des cas. Des différences de plusieurs pourcent ne sont pas rares.

## INHALTSVERZEICHNIS

Die Schlüsselformel der A-Komponente beginnt nicht mit 16.

Zweikomponenten Systeme.

Dreikomponenten Systeme.

Die A-Komponente hat eine mit 16 beginnende Schlüsselformel.

Zweikomponenten Systeme.

Dreikomponenten Systeme.

## EINLEITUNG

Wenn die Beziehung zwischen dem spezifischen Volumen und der Volumkonzentration linear ist, so ist gewöhnlich die Fluidität eine lineare Funktion der Volumkonzentration. Viele der Literaturstellen denen Daten über die Fluidität entnommen worden sind, enthalten die entsprechenden Dichten, welche aber in diesem Abschnitt nicht angegeben werden, da sie sehr vollständig in einem anderen Band (*siehe Bd. III*, S. 130) vorgefunden werden können. Es ist sehr schwer die Genauigkeit abzuschätzen. Wo Daten verschiedener Beobachter vorhanden sind, ist in sehr vielen Fällen die Übereinstimmung nicht gut. Differenzen von mehreren Prozenten sind nicht ungewöhnlich.

## INDICE

La formula chiave del componente A non comincia con 16

Sistemi a due componenti..... 26

Sistemi a tre componenti 30

Componente A ha una formula chiave che comincia con 16.

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## INTRODUZIONE

Quando il volume specifico varia linearmente con la concentrazione in volume, la fluidità è di regola una funzione lineare di questa. La maggior parte della letteratura dalla quale sono stati tratti i dati di fluidità contiene anche i corrispondenti valori di densità; questi però non sono stati riprodotti qui perchè essi sono stati riuniti in un altro volume (*v. Vol. III*, p. 130). È molto difficile valutare la precisione dei dati. La concordanza fra i valori di osservatori diversi in molti casi non è buona. Vi sono spesso differenze di alcuni percenti.

## ABBREVIATIONS, SYMBOLS AND UNITS

$\eta$ , Viscosity in poises at  $t$ , °C

$\varphi = \frac{1}{\eta}$ , Fluidity in rhes (reciprocal poises), at  $t$ , °C

## ABRÉVIATIONS, SYMBOLES ET UNITÉS

$\eta$ , Viscosité en poises à  $t$ , °C

$\varphi = \frac{1}{\eta}$ , Fluidité en rhes (poises réciproques) à  $t$ , °C

## ABKÜRZUNGEN, ZEICHEN UND EINHEITEN

$\eta$ , Viskosität in Poise, bei  $t$ , °C

$\varphi = \frac{1}{\eta}$ , Fluidität in rhes (in reziproken Poise), bei  $t$ , °C

## ABBREVIAZIONI, SIMBOLI E UNITÀ

$\eta$ , Viscosità in poises a  $t$ , °C

$\varphi = \frac{1}{\eta}$ , Fluidità in rhes (poises reciproci) a  $t$ , °C



## ABBREVIATIONS.—(Continued)

g B/l Grams of B in one liter of mixture
M B/l Moles of B in one liter of mixture
M B/l A Moles of B in one liter of A
M B/kg Moles of B in one kilogram of mixture
g B/kg A Grams of B in one kilogram of A
Wt. % B Grams B in 100 g of mixture
M % B Moles B in 100 moles of mixture
Vol. % B Volume of B in 100 volumes of mixture

## ARRANGEMENT

The following tables are divided into two sections as shown above in the table of contents. Section I is an **A-B** Table and follows the Standard Arrangement (*v. Vol. III, p. viii*). Section II is a **C**-Table and follows the **C**-arrangement.

## ABRÉVIATIONS.—(Suite)

g B/l Grammes de B par litre de mélange
M B/l Mol. gr. de B par litre de mélange
M B/l A Mol. gr. de B par litre de A
M B/kg Mol. gr. de B par kilogramme de mélange
g B/kg A Grammes de B par kg de A
Wt. % B Grammes de B dans 100 g de mélange
M % B Mol. gr. de B pour 100 mol. gr. du mélange
Vol. % B Volume de B dans 100 volumes du mélange

## ARRANGEMENT

Les tables suivantes sont divisées en deux sections, ainsi qu'il est montré ci-dessus dans la table des matières. La Section I est une Table **A-B** et elle suit l'arrangement type (*v. Vol. III, p. viii*). La Section II est une Table **C** et elle suit l'arrangement **C**.

## ABKÜRZUNGEN.—(Fortsetzung)

g B/l Gramme von B in 1 Liter der Mischung
M B/l Mole von B in 1 Liter der Mischung
M B/l A Mole von B in 1 Liter von A
M B/kg Mole von B in 1 Kilogramm der Mischung
g B/kg A Gramme von B in 1 Kilogramm von A
Wt. % B Gramme von B in 100 g der Mischung
M % B Mole von B in 100 Molen der Mischung
Vol. % B Volumen von B in 100 Volumteilen der Mischung

## ANORDNUNG

Die folgenden Tabellen sind in zwei Abschnitte, entsprechend dem obigen Inhaltsverzeichnis, geteilt. Abschnitt I ist eine **A-B** Tafel und folgt der Standardanordnung (*siehe Bd. III, S. viii*). Abschnitt II ist eine **C**-Tafel und folgt der **C**-Anordnung.

## ABBREVIAZIONI.—(Cont.)

g B/l Grammi di B in un litro di miscuglio
M B/l Molecole di B in un litro di miscuglio
M B/l A Molecole di B in un litro di A
M B/kg Molecole di B in un chilo di miscuglio
g B/kg A Grammi di B in un chilo di A
Wt. % B Grammi di B in 100 g di miscuglio
M % B Molecole di B in 100 di miscuglio
Vol. % B Volume di B in 100 di miscuglio

## ORDINAMENTO

Le tabelle seguenti sono divise in due sezioni, come si è visto sopra, nell'indice. La Sezione I è una Tabella **A-B** e segue l'ordinamento standard (*v. Vol. III, p. viii*). La Sezione II è una Tabella **C** e segue l'ordinamento **C**.

## THE A-COMPONENT KEY-FORMULA DOES NOT BEGIN WITH 16

A-B Table, Standard Arrangement (*v. Vol. III, p. viii*)

## TWO-COMPONENT SYSTEMS

<b>H<sub>2</sub>SO<sub>4</sub></b>				
B = HNO <sub>3</sub> (15)				
Wt. % B	Vol. % B	$\varphi_{10}$	$\varphi_{20}$	$\varphi_{40}$
0.00	0.00	3.00	4.50	7.90
12.50	14.76	1.55	2.55	5.45
25.00	28.77	1.80	2.85	6.30
37.50	42.11	2.60	3.70	8.35
50.00	58.40	5.40	8.25	15.05
62.50	66.89	7.75	11.55	20.10
75.00	78.45	29.25	37.90	59.20
87.50	89.46	41.40	52.35	75.80
100.00	100.00	96.40	113.9	147.1

<b>NH<sub>3</sub></b>	
B = NH <sub>4</sub> Br (48)	
M B/l	$\varphi_{-33.5}$
0.334	329.8
0.644	300.9
1.10	255.3
1.89	185.8
4.07	68.46

B = Cu(NO <sub>3</sub> ) <sub>2</sub> ·4NH <sub>3</sub> (48)	
0.105	347.2
0.226	313.4
0.362	287.7
0.618	235.5
1.32	127.2

B = AgI (48)	
0.202	355.9
0.359	335.6

B = AgI.—(Continued)	
M B/l	$\varphi_{-33.5}$
0.846	284.8
1.98	195.9
3.38	108.6
7.26	10.12

B = AgNO <sub>3</sub> (48)	
0.162	349.2
0.276	329.6
0.592	282.7

B = NaNO <sub>3</sub> (48)	
0.056	367.1
0.107	363.1
0.145	359.7
0.182	356.1
0.246	347.4
0.310	341.3
0.420	328.5
0.528	314.7
0.900	275.7
1.53	224.0
3.30	113.8

B = KI (48)	
0.066	372.8
0.110	366.3
0.187	355.8
0.321	348.3
0.545	319.2
1.17	254.3

## B = KI.—(Continued)

M B/l	$\varphi_{-33.5}$
2.01	189.7
4.31	69.17
0.5	48.06*
1.0	40.40*
2.5	23.43*

\* At pressure of saturated vapor.

<b>Bi</b>			
B = BiCl <sub>3</sub> (3)			
M % A	$\varphi_{260}$	$\varphi_{270}$	$\varphi_{280}$
0.0	3.12	3.39	3.70
9.3	2.44	2.70	2.98
18.6			2.13
M % A	$\varphi_{290}$	$\varphi_{300}$	$\varphi_{310}$
0.0	4.00	4.35	4.65
9.3	3.28	3.51	3.85
18.6	2.35	2.63	2.90
30.2		1.64	1.84
M % A	$\varphi_{320}$	$\varphi_{330}$	$\varphi_{340}$
0.00	4.88	5.26	5.56
9.3	4.08	4.26	4.54
18.6	3.12	3.33	3.51
30.2	2.02	2.22	3.51
40.2	1.14	1.29	

<b>Cl<sub>2</sub></b>	
B = CCl <sub>4</sub> (98)	
Wt. % B	$\varphi_{25}^*$
97.24	124.8
98.18	120.3
98.92	117.3
100.0	112.6

\* At pressure of saturated vapor.

**HCl**B = CH<sub>3</sub>O, Methyl alcohol (51.5)B = C<sub>2</sub>H<sub>5</sub>O, Ethyl alcohol (51.5)**HBr**B = C<sub>2</sub>H<sub>5</sub>O, Ethyl alcohol (51.5)**I<sub>2</sub>**

B = CS <sub>2</sub> (117)	
g A/l	$\varphi_{25}$
0.0	248.7
6.8	248.4
13.6	246.8
27.5	244.7
54.0	243.9
108.0	233.4
214.6	222.0

B = CHCl <sub>3</sub> (117)	
0.0	168.3
1.5	169.9
2.9	168.4
5.7	168.5
11.5	169.2
22.9	168.8
44.9	167.7

B = C <sub>2</sub> H <sub>5</sub> O, Ethyl alcohol (117)	
0.0	89.8
2.1	89.2
4.2	89.0
8.4	88.6



**B = C<sub>2</sub>H<sub>5</sub>O.—(Continued)**

g A/l	$\varphi_{25}$
16.6	87.8
33.2	86.4
65.9	84.7

**B = C<sub>4</sub>H<sub>10</sub>O, Ethyl ether (117)**

0.0	416.7
6.7	418.4
13.2	413.7
26.2	403.7
52.0	393.8
95.0	373.1
189.7	333.6

**B = C<sub>6</sub>H<sub>6</sub>, Benzene (117)**

0.0	165.1
4.1	165.2
7.7	164.8
14.2	164.3
28.4	162.8
56.4	159.8
72.4	154.7

**S****B = CS<sub>2</sub> (4)**

Wt. % A	$\varphi_{25}$
0.0*	282.5
5.35*	261.8
13.12*	235.3
3.61†	268.8
7.92†	256.4
3.25‡	260.4
3.11*	
6.60‡	235.8
6.31*	

\* = Rhombic, S<sub>λ</sub>.† = Engel, S<sub>p</sub>.‡ = Magnus, S<sub>r</sub>.**SO<sub>2</sub>****B = CCl<sub>4</sub>\* (98)**

Wt. % B	$\varphi_{25}$
0.0	391.3
26.42	352.6
35.79	334.8
48.60	305.1
68.93	239.9
73.28	223.0
85.01	179.0
92.11	149.4
98.870	121.9
99.220	119.7
99.315	118.9
99.672	116.7
100.00	112.7

**B = CS<sub>2</sub>\* (98)**

97.41	296.8
98.18	295.7
98.91	293.7
100.00	290.0

**B = CHCl<sub>3</sub>\* (98)**

97.10	199.1
97.44	197.9
98.12	194.6
100.00	184.4

\* At pressure of saturated vapor.

**B = CH<sub>3</sub>O, Methyl alcohol\***

(98)

Wt. % B	$\varphi_{25}$
0.0	391.3
18.16	320.7
20.27	310.3
25.10	291.2
29.29	281.1
40.89	239.3
51.27	215.5
68.76	191.7
74.47	188.8
91.98	184.4
100.00	183.2

**B = C<sub>3</sub>H<sub>8</sub>O, Acetone (98)**

0.00	390.7
12.32	352.1
20.80	331.5
44.90	293.7
47.83	293.3
57.56	288.1
69.40	291.5
73.48	292.9
77.78	297.2
81.98	301.8
94.66	320.3
100.00	328.9

**B = C<sub>4</sub>H<sub>10</sub>O, Ethyl ether (98)**

0.00	390.7
30.46	347.7
50.56	347.2
57.00	356.6
63.71	362.4
66.47	363.2
85.80	409.3
88.30	416.7
91.67	425.0
95.00	434.3
100.00	448.2

**B = C<sub>6</sub>H<sub>6</sub>, Benzene\* (98)**

0.00	390.7
26.39	329.8
50.44	265.7
52.58	263.3
80.76	203.7
92.62	185.2
95.48	177.6
97.28	174.2
100.00	167.8

**B = C<sub>7</sub>H<sub>16</sub>, Heptane\* (98)**

96.82	268.9
98.29	265.5
100.00	259.4

**B = C<sub>7</sub>H<sub>8</sub>, Toluene\* (98)**

0.00	390.7
21.43	326.8
27.95	321.9
52.00	256.7
52.92	256.1
71.96	219.4
72.76	217.5
74.72	215.7

\* At pressure of saturated vapor.

**B = C<sub>7</sub>H<sub>8</sub>.\*—(Continued)**

Wt. % B	$\varphi_{25}$
86.00	204.9
92.52	195.3
96.79	187.3
98.71	183.5
100.00	181.4

**B = C<sub>8</sub>H<sub>10</sub>, Xylene\* (98)**

84.57	187.5
89.08	178.5
91.22	175.6
93.28	171.8
95.00	169.4
96.48	167.6
100.00	165.5

**H<sub>2</sub>S****B = CHCl<sub>3</sub>\* (98)**

99.713	192.1
99.807	190.2
100.00	184.4

\* At pressure of saturated vapor.

**H<sub>2</sub>SO<sub>4</sub>****B = C<sub>2</sub>H<sub>4</sub>O<sub>3</sub>, Acetic acid (26)**

Wt. % B	$\varphi_{15}$	$\varphi_{76.5}$
0.00	3.712	19.87
9.93	2.384	13.94
29.88	0.729	9.33
50.18	0.872	10.6
70.07	3.190	25.7
90.01	26.20	79.6
100.00	75.00	177.4

**B = C<sub>2</sub>H<sub>6</sub>SO<sub>4</sub>, Dimethyl sulfate (26)**

Wt. % B	$\varphi_0$	$\varphi_{76.5}$
0.00	2.06	18.9
24.98	3.19	24.4
50.15	5.48	35.6
75.02	14.29	66.9
100.00	36.60	124.7

**B = C<sub>4</sub>H<sub>10</sub>O, Ethyl ether (118)**

Wt. % B	$\varphi_{30}$
0.0	4.76
2.50	5.30
5.00	6.26
10.00	7.64
15.00	7.86
20.00	7.46
25.00	6.68
30.00	6.28
35.00	6.19
40.00	6.96
45.00	9.09
50.00	13.88
56.436	28.74
60.875	45.58
70.399	101.8
78.221	172.7
83.223	229.4
90.172	322.9
93.370	366.3
100.00	468.6

**NH<sub>3</sub>****B = CH<sub>3</sub>N<sub>2</sub>O, Urea (48)**

M B/l	$\varphi_{-12.5}$
0.333	356.4
0.376	351.9
0.567	340.2
0.806	319.1
0.966	306.0
2.076	243.0

**B = C<sub>12</sub>H<sub>22</sub>O<sub>11</sub>, Sucrose (48)**

0.022	367.2
0.039	360.0
0.070	345.0
0.124	321.4
0.220	278.0
0.3918	164.3
0.921	44.76

**NH<sub>4</sub>Br****B = CH<sub>3</sub>NO, Formamide (23)**

M B/l	$\varphi_{15}$	$\varphi_{25}$	$\varphi_{35}$
0.0	23.2	30.7	39.3
0.1	22.7	30.6	38.0
0.25	22.0	28.9	37.3
0.5	20.9	27.7	36.0

**NH<sub>4</sub>I****B = CH<sub>3</sub>NO, Formamide (23)**

M A/l	$\varphi_{15}$	$\varphi_{25}$	$\varphi_{35}$
0.0	23.8	31.2	40.1
0.1	22.9	30.2	38.4
0.25	21.9	29.3	37.5
0.5	19.6	25.9	33.3

**NH<sub>4</sub>NO<sub>3</sub>****B = CH<sub>3</sub>NO, Formamide (63)**

M A/l	$\varphi_{15}$	$\varphi_{25}$	$\varphi_{35}$
0.0	22.89	30.3	38.0
0.1	22.35	29.5	36.4
0.25	22.00	29.3	36.4
0.5	21.37	28.4	35.4

**SbCl<sub>3</sub>****B = C<sub>2</sub>H<sub>6</sub>O, Acetone (87, 88)**

M % B	$\varphi_{25}$	$\varphi_{50}$
33.3	5.52	18.83
38	5.96	
50	10.54	24.86
66.6	28.2	52.13
75	50.6	84.53
100	295.0	
M % B	$\varphi_{50}$	$\varphi_{80}$
0	24.55	46.34
20	17.53	43.80
23	17.50	39.58
25	17.08	41.44
30	17.56	41.51
33.3	18.83	42.37

**B = C<sub>4</sub>H<sub>10</sub>O, Ethyl ether (87, 88)**

M % A	$\varphi_{25}$	$\varphi_{32}$
0	409.8	429.2
25	99.2	108.2
33.4	51.2	59.6
50	15.3	18.98



**SbCl<sub>3</sub>—(Continued)****B = C<sub>6</sub>H<sub>10</sub>O—(Continued)**

M % A	$\varphi_{25}$	$\varphi_{32}$
70	6.53	8.64
75	5.80	7.94
80	5.55	7.49
85	5.91	7.85

**B = C<sub>6</sub>H<sub>6</sub>, Benzene (84, 85)**

Wt. % B	$\varphi_{75}$
0	42.4
15	44.3
25	48.8
33.4	53.9
50	76.9
66.6	127.2
75	165.0
100	296.7

**B = C<sub>6</sub>H<sub>7</sub>N, Aniline (84, 85)**

M % B	$\varphi_{95}$	$\varphi_{125}$
0.0	138.1	432.9
25.0	16.51	92.42
33.33	6.51	
45.0	2.89	
50.0	2.64	28.05
52.5	2.67	28.00
55.0	2.82	28.22
66.67	5.71	
100.00	65.27	201.2

**B = C<sub>13</sub>H<sub>12</sub>, Diphenylmethane (84, 85)**

M % B	$\varphi_{100}$
0	65.6
15	50.4
20	49.7
25	49.7
34.87	53.4
50	67.1
100	120.9

**B = C<sub>19</sub>H<sub>16</sub>, Triphenylmethane (84, 85)**

	$\varphi_{100}$
0	65.6
33.33	30.85
50	29.5
55	28.9
60	28.5
66.67	29.0
100	31.0

**SbBr<sub>3</sub>****B = C<sub>6</sub>H<sub>5</sub>O, Acetophenone (84, 85)**

M % A	$\varphi_{25}$	$\varphi_{50}$	$\varphi_{95}$
0	61.8	80.3	153.1
25	9.43	17.78	40.34
40	1.64	3.23	19.40
45	1.27	2.62	15.65
48	1.108	2.549	14.93
50	1.036	2.353	14.34
51	1.069	2.439	13.82
52		2.45	13.19
60	1.872	4.44	16.60
70	3.167	7.39	23.26
85		15.80	25.11
100			30.22

**B = C<sub>13</sub>H<sub>10</sub>O, Benzophenone (84, 85)**

Wt. % A	$\varphi_{25}$	$\varphi_{95}$
0.0	7.35	57.3
33.33	0.552	26.8
50.0	0.2086	19.9
55.0	0.1812	
60.0	0.1766	17.7
66.67	0.2118	17.2
70.0		17.4
75.0		17.7
100.0		30.2

**SnCl<sub>4</sub>****B = C<sub>2</sub>H<sub>5</sub>O<sub>2</sub>, Ethyl formate (87, 88)**

M % B	$\varphi_{30}$	$\varphi_{40}$	$\varphi_{50}$
0	124.1	137.9	149.7
25	65.5	77.4	89.69
50	14.56	20.19	26.65
64	2.27	4.25	7.02
66.5	1.73	3.38	5.97
68	1.91	3.62	6.21
70	3.21	5.25	8.03
75	113.8	15.66	20.39
100	266.7	292.4	321.5

**B = C<sub>4</sub>H<sub>8</sub>O<sub>2</sub>, Ethyl acetate (87, 88)**

M % B	$\varphi_{25}$	$\varphi_{50}$	$\varphi_{70}$
0	108.8	149.7	166.7
30	52.82	80.32	100.8
50	15.50	30.93	47.9
64.1	2.60	9.79	22.8
65.4	2.14	9.16	21.7
66.6	1.99	8.89	21.6
67.4	2.23	9.53	22.8
75	8.51	20.2	36.3
100	226.8	289.9	353

**B = C<sub>4</sub>H<sub>8</sub>O<sub>2</sub>, Propyl formate (87, 88)**

M % B	$\varphi_{50}$	$\varphi_{70}$
0	149.7	166.7
25	83.1	111.6
50	23.35	39.56
65	6.53	16.13
66.6	6.07	15.25
68	6.67	16.49
75	17.06	30.97
100	253.8	307.7

**B = C<sub>5</sub>H<sub>10</sub>O<sub>2</sub>, Ethyl propionate (80, 81)**

M % B	$\varphi_{25}$	$\varphi_{70}$
0	108.8	166.4
10	90.09	149.9
25	62.62	123.9
40	34.66	89.29
50	18.96	65.92
60	7.47	46.58
65	4.67	44.50
65.20	4.87	46.17
65.87	4.86	47.06
66.67	4.97	48.37
67.11	5.04	48.3
70	7.29	53.0

**B = C<sub>5</sub>H<sub>10</sub>O<sub>2</sub>—(Continued)**

M % B	$\varphi_{25}$	$\varphi_{70}$
75	16.7	66.6
90	95.1	276.2
100	189.0	304.0

**B = C<sub>5</sub>H<sub>10</sub>O<sub>2</sub>, Methyl butyrate (87, 88)**

M % B	$\varphi_{25}$	$\varphi_{50}$	$\varphi_{70}$
0	108.8	149.7	166.7
66.5	4.53	20.62	47.8
100	18.32	266.0	320.5

**B = C<sub>6</sub>H<sub>6</sub>, Benzene (87, 88)**

M % B	$\varphi_{25}$	$\varphi_{70}$
0	108.8	166.7
25	140.2	204.5
50	156.7	250.6
75	166.7	266.7
100	164.5	275.5

**B = C<sub>6</sub>H<sub>12</sub>O<sub>2</sub>, Ethyl butyrate (87, 88)**

M % B	$\varphi_{25}$	$\varphi_{50}$	$\varphi_{70}$
0	108.8	149.7	166.7
25	52.8	80.3	100.8
50	24.2	34.9	55.8
64	5.32	18.8	41.6
65	5.04	18.7	42.2
66	5.10	18.9	42.5
66.7	5.18	19.1	42.9
67.5	5.50	19.9	44.2
69.2	6.84	22.3	48.1
75	15.56	36.3	66.1
100	159.2	214.6	311.5

**B = C<sub>6</sub>H<sub>10</sub>O<sub>2</sub>, Ethyl benzoate (87, 88)**

M % B	$\varphi_{25}$	$\varphi_{50}$	$\varphi_{70}$
0	49.2	78.1	104.7
25	12.6	37.8	64.3
33.4	8.63	31.3	56.6
35	8.49	31.0	56.3
37.5	8.43	30.3	55.7
40	8.44	29.7	53.9
45	9.48	29.9	54.0
50	12.1	32.7	57.4
70	36.8	64.2	91.0
100	108.8	149.9	166.7

**HgCl<sub>2</sub>****B = CH<sub>3</sub>NO, Formamide (64)**

M A/l	$\varphi_{15}$	$\varphi_{25}$	$\varphi_{35}$
0.0	23.2	31.0	39.8
0.1	22.2	29.6	
0.25	21.3	28.3	

**AgI****B = CH<sub>3</sub>N, Methylamine (48)**

M A/l	$\varphi_0$
1.08	293.9
1.24	282.7
2.31	197.0

**B = C<sub>2</sub>H<sub>7</sub>N, Dimethylamine (40)**

M A/l	$\varphi_{-22.5}$
0.3195	199.1
0.6375	179.9
1.366	125.1

**B = C<sub>2</sub>H<sub>7</sub>N, Ethylamine (40)**

M A/l	$\varphi_{-22.5}$
0.1012	165.4
0.1728	156.9
0.3494	144.5
0.6339	125.1
1.116	100.4

**AgNO<sub>3</sub>****B = CH<sub>3</sub>N, Methylamine (48); cf. (75)**

	$\varphi_{-22.5}$
0.99	221.6
1.29	180.8
1.48	152.6
1.91	111.1
2.76	55.64
3.57	29.78

**B = C<sub>2</sub>H<sub>3</sub>N, Acetonitrile (123)**

Wt. % B	$\varphi_{25}$
43.07	15.4
68.09	95.6
85.93	190.8
95.20	244.5
100.00	278.6

**B = C<sub>2</sub>H<sub>7</sub>N, Ethylamine (40)**

M A/l	$\varphi_{-22.5}$
0.03436	168.2
0.07045	159.5
0.1402	140.8
0.2785	123.9
0.5420	103.1
0.7411	72.78
1.999	14.09

**B = C<sub>3</sub>H<sub>7</sub>N, Propylamine (40)**

	$\varphi_{-22.5}$
0.1387	82.1
0.2802	66.7

**B = C<sub>5</sub>H<sub>5</sub>N, Pyridine (121)**

Wt. % B	$\varphi_{25}$
73.93	17.6
85.12	48.8
90.41	74.3
95.96	90.6
100.00	112.2

**B = C<sub>6</sub>H<sub>5</sub>ClN, *m*-Chloro-aniline (121)**

M % B	$\varphi_{25}$
92.11	10.9
96.91	20.7
98.82	25.5
99.49	27.3
99.81	28.0
99.92	28.4
100.00	28.6

**B = C<sub>6</sub>H<sub>7</sub>N, Aniline (121)**

Wt. % B	$\varphi_{25}$
89.79	11.16
93.92	16.67
96.98	21.79
98.13	23.47
100.00	27.03

**B = C<sub>6</sub>H<sub>7</sub>N, Quinoline (121)**

	$\varphi_{-22.5}$
94.08	14.4
97.19	21.5
98.60	25.4
100.00	29.6



CoBr <sub>2</sub>			
B = CH <sub>3</sub> NO, Formamide (64)			
M A/l	φ <sub>15</sub>	φ <sub>25</sub>	φ <sub>35</sub>
0.0	23.25	31.05	39.84
0.1	20.44	27.03	34.88

Ca(NO <sub>3</sub> ) <sub>2</sub>	
B = C <sub>2</sub> H <sub>5</sub> O, Ethyl alcohol (155)	
Wt. % B	φ <sub>25</sub>
96	5.0
97	12.0
98	26.0
99	51.0
100	92.3

Sr(NO <sub>3</sub> ) <sub>2</sub>			
B = CH <sub>3</sub> NO, Formamide (63)			
M A/l	φ <sub>15</sub>	φ <sub>25</sub>	φ <sub>35</sub>
0.0	22.7	30.1	37.8
0.1	20.2	27.1	33.8
0.25	17.4	23.5	29.8

BaCl <sub>2</sub>			
B = CH <sub>3</sub> NO, Formamide (23)			
M A/l	φ <sub>15</sub>	φ <sub>25</sub>	φ <sub>35</sub>
0.0	23.3	31.1	39.8
0.1	20.2	27.0	34.8

Ba(NO <sub>3</sub> ) <sub>2</sub>			
B = CH <sub>3</sub> NO, Formamide (63)			
M A/l	φ <sub>15</sub>	φ <sub>25</sub>	φ <sub>35</sub>
0.0	22.5	30.0	37.7
0.1	20.4	27.1	34.1
0.25	17.2	22.3	29.5

Ba(CNS) <sub>2</sub>	
B = C <sub>2</sub> H <sub>7</sub> N, Ethylamine (40)	
M A/l	φ <sub>33.5</sub>
0.1392	139.0
0.2809	108.3

LiCl	
B = CH <sub>3</sub> N, Methylamine (48)	
M A/l	φ <sub>0</sub>
0.355	356.5
0.526	315.8
0.985	232.7
1.35	182.4
2.01	107.0

B = C <sub>2</sub> H <sub>5</sub> O, Ethyl alcohol (143)	
g A/kg B	φ <sub>15</sub>
0.00	75.9
2.587	71.2
4.824	67.7
10.48	60.9
20.93	50.6
35.01	40.3
45.16	33.4

LiNO <sub>3</sub>			
B = CH <sub>3</sub> NO, Formamide (64)			
M A/l	φ <sub>15</sub>	φ <sub>25</sub>	φ <sub>35</sub>
0.0	23.4	31.3	40.0
0.15	22.4	31.7	37.8
0.25	21.2	28.0	35.9
0.5	19.3	25.8	33.1

LiCHO <sub>2</sub>	
Formate	
B = CH <sub>2</sub> O <sub>2</sub> , Formic acid (133)	
M A/l	φ <sub>18</sub>
0.000	53.6
0.08513	50.6
0.1292	49.3
0.1810	47.9
0.2703	45.2
0.3441	43.4
0.4335	41.5
M A/l	φ <sub>25</sub>
0.000	62.3
0.08583	59.0
0.1347	57.2
0.2039	55.0
0.2605	53.2
0.4064	49.1
0.4669	47.5

B = CH <sub>3</sub> NO, Formamide (63)			
M A/l	φ <sub>15</sub>	φ <sub>25</sub>	φ <sub>35</sub>
0.0	22.7	30.0	37.5
0.15	21.6	28.6	35.8
0.25	19.6	26.4	32.9
0.5	17.6	23.7	29.8

NaBr			
B = CH <sub>3</sub> NO, Formamide (64)			
M A/l	φ <sub>15</sub>	φ <sub>25</sub>	φ <sub>35</sub>
0.0	23.4	31.3	39.8
0.1	22.1	29.3	37.5
0.25	20.5	27.2	35.2
0.5	17.9	24.5	32.0

B = CH <sub>3</sub> O, Methyl alcohol (42.5)	
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NaI			
B = CH <sub>3</sub> NO, Formamide (64)			
M A/l	φ <sub>15</sub>	φ <sub>25</sub>	φ <sub>35</sub>
0.0	23.2	30.3	38.9
0.1	22.1	29.6	37.7
0.25	20.7	27.5	35.7
0.5	18.4	25.0	32.6

B = CH <sub>3</sub> O, Methyl alcohol (42.5)	
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B = C <sub>2</sub> H <sub>5</sub> O, Ethyl alcohol (155); cf. (51.5)			
M A/l	φ <sub>15</sub>	φ <sub>25</sub>	φ <sub>35</sub>
0.0	77.4	94.9	114.8
0.125	70.2	84.0	101.9

NaNO <sub>3</sub>			
B = CH <sub>3</sub> NO, Formamide (63)			
M A/l	φ <sub>15</sub>	φ <sub>25</sub>	φ <sub>35</sub>
0.0	22.7	30.0	37.5
0.1	21.5	28.5	35.9
0.25	19.9	26.8	33.6
0.5	17.9	24.3	31.0

B = CH <sub>3</sub> N, Methylamine (48)	
M A/l	φ <sub>0</sub>
0.226	389
0.387	365
0.575	338
1.075	267

NaCHO <sub>2</sub>	
Formate	
B = CH <sub>2</sub> O <sub>2</sub> , Formic acid (134)	
M A/l	φ <sub>0</sub>
0.0	53.6
0.06191	51.2
0.08267	50.5
0.1283	49.0
0.2107	46.4
0.3027	43.9
0.4925	38.9
0.5642	37.4
M A/l	φ <sub>25</sub>
0.04228	59.9
0.06941	58.8
0.1124	57.4
0.2382	52.8
0.4460	46.7
0.5759	43.4
0.7435	39.5
0.9876	34.2

B = CH <sub>3</sub> NO, Formamide (63)			
M A/l	φ <sub>15</sub>	φ <sub>25</sub>	φ <sub>35</sub>
0.0	22.7	30.0	37.5
0.1	21.4	28.5	35.7
0.25	19.4	26.2	32.9
0.5	17.0	23.3	29.9

NaC <sub>7</sub> H <sub>5</sub> O <sub>2</sub>			
Benzoate			
B = CH <sub>3</sub> NO, Formamide (63)			
M A/l	φ <sub>15</sub>	φ <sub>25</sub>	φ <sub>35</sub>
0.0	22.7	30.1	37.3
0.1	20.8	27.7	35.0
0.25	18.2	24.7	31.6

NaC <sub>7</sub> H <sub>5</sub> O <sub>3</sub>			
Salicylate			
B = CH <sub>3</sub> NO, Formamide (63)			
M A/l	φ <sub>15</sub>	φ <sub>25</sub>	φ <sub>35</sub>
0.0	22.8	30.1	37.8
0.1	20.9	28.0	35.0
0.25	18.6	25.1	31.9

Na <sub>2</sub> C <sub>4</sub> H <sub>4</sub> O <sub>4</sub>			
Succinate			
B = CH <sub>3</sub> NO, Formamide (63)			
M A/l	φ <sub>15</sub>	φ <sub>25</sub>	φ <sub>35</sub>
0.0	22.7	30.1	37.3
0.01	19.0	25.6	32.1

NaC <sub>6</sub> H <sub>5</sub> SO <sub>3</sub>			
Benzenesulfonate			
B = CH <sub>3</sub> NO, Formamide (63)			
M A/l	φ <sub>15</sub>	φ <sub>25</sub>	φ <sub>35</sub>
0.0	22.8	30.15	37.8
0.1	21.2	28.14	35.3

NaC <sub>7</sub> H <sub>3</sub> N <sub>2</sub> O <sub>6</sub>			
1, 3, 5-Dinitrobenzoate			
B = CH <sub>3</sub> NO, Formamide (63)			
M A/l	φ <sub>15</sub>	φ <sub>25</sub>	φ <sub>35</sub>
0.0	22.7	30.1	37.7
0.1	20.2	27.2	33.9

NaC <sub>7</sub> H <sub>6</sub> NO <sub>2</sub>			
m-Aminobenzoate			
B = CH <sub>3</sub> NO, Formamide (63)			
M A/l	φ <sub>15</sub>	φ <sub>25</sub>	φ <sub>35</sub>
0.0	22.7	30.1	37.7
0.1	20.5	27.2	34.4

Na <sub>2</sub> CrO <sub>4</sub>		
B = CH <sub>3</sub> NO, Formamide (64)		
M A/l	φ <sub>15</sub>	φ <sub>25</sub>
0.0	23.2	31.0
0.1	20.1	27.3

KCl			
B = CH <sub>3</sub> NO, Formamide (64)			
M A/l	φ <sub>15</sub>	φ <sub>25</sub>	φ <sub>35</sub>
0.0	23.2	30.2	39.3
0.1	21.9	29.5	37.8
0.25	21.2	28.0	35.8
0.5	19.0	25.5	33.3

B = CH <sub>3</sub> O, Methyl alcohol (42.5)	
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KBr	
B = CH <sub>3</sub> O, Methyl alcohol (42.5)	

KI	
B = CH <sub>3</sub> O, Methyl alcohol (143); for more recent data, cf. (42.5)	

g A/kg B	$\varphi_{15}$
5.74	154.7
11.87	152.3
22.65	148.4
45.74	139.5
76.74	130.2
116.94	121.5

g A/kg B	$\varphi_{25}$	$\varphi_{40}$
17.86	173.0	214.6
35.93	166.2	205.6
70.39	155.0	192.0
97.72	147.8	183.7

B = CH <sub>3</sub> NO, Formamide (64)			
M A/l	φ <sub>15</sub>	φ <sub>25</sub>	φ <sub>35</sub>
0.0	23.2	30.3	38.9
0.1	22.6	29.8	38.0
0.25	21.6	28.4	36.8
0.5	20.1		34.7

B = CH <sub>3</sub> N, Methylamine (48)	
M A/l	φ <sub>0</sub>
1.22	227.7

B = C <sub>2</sub> H <sub>5</sub> O, Ethyl alcohol (143)	
g A/kg B	φ <sub>15</sub>
4.74	74.5
8.20	73.4
13.37	72.2

KNO <sub>3</sub>			
B = CH <sub>3</sub> NO, Formamide (63)			
M A/l	φ <sub>15</sub>	φ <sub>25</sub>	φ <sub>35</sub>
0.0	22.9	30.3	38.0
0.1	21.8	29.0	36.4
0.25	20.7	27.7	35.5
0.5	19.4	25.9	32.9



**KCHO<sub>2</sub>**

Formate

B = CH<sub>2</sub>O<sub>2</sub>, Formic acid (133)

M A/l	$\varphi_{25}$
0.0548	59.5
0.0733	58.9
0.1787	55.2
0.1888	54.9
0.2099	54.6
0.2619	53.1
0.2878	52.7
0.3195	51.5
0.3917	49.4
0.4445	48.4
0.6104	44.7

**KCNS**B = CH<sub>3</sub>NO, Formamide (64)

M A/l	$\varphi_{15}$	$\varphi_{25}$	$\varphi_{35}$
0.0	23.3	30.7	39.1
0.1	22.9	30.5	38.8
0.25	21.8	28.8	36.9
0.5	20.4	27.4	35.2

**RbCl**B = CH<sub>3</sub>NO, Formamide (64)

M A/l	$\varphi_{15}$	$\varphi_{25}$	$\varphi_{35}$
0.0	23.3	30.7	39.0
0.1	22.3	29.4	38.1
0.25	20.9	27.7	36.0
0.5	19.1	25.8	33.8

**RbBr**B = CH<sub>3</sub>NO, Formamide (64)

M A/l	$\varphi_{15}$	$\varphi_{25}$	$\varphi_{35}$
0.0	23.2	30.7	39.0
0.1	22.4	29.5	37.8
0.25	21.5	28.6	36.8

## THREE-COMPONENT SYSTEMS

**Argon**B = O<sub>2</sub>C = N<sub>2</sub> (147, 148)

% A	% K	$\varphi$
9.5% B; 89% C		
1.5	77.91	625.4
35% B; 63% C		
2	79.57	595.9
61% B; 36% C		
3	82.34	536.1
96% B; 1% C		
3	89.62	527.6

**I<sub>2</sub>**

B = KI

C = CH<sub>3</sub>O, Methyl alcohol (20)

g A/l	g B/l	$\varphi_{25-5}$
126.92	0.00	165.1
112.86	18.44	159.1
111.07	20.75	158.2
108.78	23.74	157.3
105.73	27.73	155.6
101.54	33.20	153.5

**RbI**B = CH<sub>3</sub>NO, Formamide (64)

M A/l	$\varphi_{15}$	$\varphi_{25}$	$\varphi_{35}$
0.0	23.80	31.18	40.06
0.1	22.56	29.87	37.97
0.25	21.54	28.55	36.54
0.5	20.22	27.66	34.90

**RbNO<sub>3</sub>**B = CH<sub>3</sub>NO, Formamide (64)

M A/l	$\varphi_{15}$	$\varphi_{25}$	$\varphi_{35}$
0.0	23.3	30.7	39.0
0.1	22.6	29.9	38.2
0.25	21.8	29.2	37.4

**RbCHO<sub>2</sub>**

Formate

B = CH<sub>3</sub>NO, Formamide (63)

M A/l	$\varphi_{25}$
0.0	30.4
0.1	29.1
0.25	28.1

**CsCl**B = CH<sub>3</sub>NO, Formamide (23)

M A/l	$\varphi_{15}$	$\varphi_{25}$	$\varphi_{35}$
0.0	23.2	30.8	
0.1	22.3	29.5	37.7
0.25	21.1	28.0	35.9

**CsNO<sub>3</sub>**B = CH<sub>3</sub>NO, Formamide (23)

M A/l	$\varphi_{15}$	$\varphi_{25}$	$\varphi_{35}$
0.0	23.2	30.8	
0.1	22.4	29.7	37.9
0.25	21.7	28.8	36.7

**NH<sub>4</sub>Br**B = CH<sub>3</sub>O, Methyl alcoholC = C<sub>2</sub>H<sub>5</sub>O<sub>2</sub>, Glycerol (52)

$\varphi_{25}$	$\varphi_{35}$	$\varphi_{45}$
No solute		
0.0 Wt. % C in (B + C)		
171.2	197.4	223.7
25.0 Wt. % C in (B + C)		
53.0	67.5	83.7
50.0 Wt. % C in (B + C)		
10.4	15.4	22.5
75.0 Wt. % C in (B + C)		
1.61	2.84	4.79
100.0 Wt. % C in (B + C)		
0.165	0.368	0.74
0.1N NH <sub>4</sub> Br		
0.0 Wt. % C in (B + C)		
159.9	184.8	211.2
25.0 Wt. % C in (B + C)		
48.5	62.1	76.0
50.0 Wt. % C in (B + C)		
10.8	15.9	22.9
75.0 Wt. % C in (B + C)		
1.67	2.99	4.97
100.0 Wt. % C in (B + C)		
0.165	0.368	0.74

B = C<sub>2</sub>H<sub>5</sub>O, Ethyl alcoholC = C<sub>2</sub>H<sub>5</sub>O<sub>2</sub>, Glycerol (52)

$\varphi_{25}$	$\varphi_{35}$	$\varphi_{45}$
No solute		
0.0 Wt. % C in (B + C)		
93.7	115.2	137.7
25.0 Wt. % C in (B + C)		
23.9	32.8	43.4
50.0 Wt. % C in (B + C)		
4.71	7.40	11.5
75.0 Wt. % C in (B + C)		
0.972	1.83	3.22
100.0 Wt. % C in (B + C)		
0.165	0.368	0.740
0.1N NH <sub>4</sub> Br		
0.0 Wt. % C in (B + C)		
86.1	105.1	125.3
25.0 Wt. % C in (B + C)		
22.7	31.0	40.9
50.0 Wt. % C in (B + C)		
4.73	7.55	11.54
75.0 Wt. % C in (B + C)		
0.92	1.73	3.04
100.0 Wt. % C in (B + C)		
0.155	0.349	0.714

**Cu(NO<sub>3</sub>)<sub>2</sub>**B = C<sub>2</sub>H<sub>5</sub>O, Ethyl alcoholC = C<sub>2</sub>H<sub>5</sub>O, Acetone (61)

Wt. %	$\varphi_{25}$	$\varphi_{35}$
No solute		
0	53.9	90.4
25	96.1	148.9
50	147.0	205.2
75	200.4	264.8
100	244.1	308.9
0.2N Cu(NO <sub>3</sub> ) <sub>2</sub>		
Wt. %	$\varphi_{25}$	$\varphi_{35}$
0	72.8	
25	118.4	
50	170.6	
75	223.0	
100	263.5	

\* Wt. = Wt. % C in (B + C).

**AgNO<sub>3</sub>**B = C<sub>2</sub>H<sub>5</sub>N, AcetonitrileC = C<sub>2</sub>H<sub>5</sub>N, Pyridine (122)

Wt. % A in solv.	$\varphi_{25}$
0.00	172.1
5.05	146.2
9.17	120.3
16.41	78.7
29.04	33.3

B = C<sub>2</sub>H<sub>5</sub>N, PyridineC = C<sub>2</sub>H<sub>5</sub>N, Aniline (121)

Wt. % A in solv.	$\varphi_{25}$
0.00	53.8
4.063	40.7
10.67	24.6
17.74	12.22
29.40	25.9

B = C<sub>2</sub>H<sub>5</sub>N; C = C<sub>2</sub>H<sub>5</sub>N.—

(Continued)

Solvent = 1 Vol. B + 4 Vol. C

Wt. % A in solv.	$\varphi_{25}$
0.00	36.6
3.72	28.0
7.31	21.0
18.29	6.96

**CoCl<sub>2</sub>**B = CH<sub>3</sub>O, Methyl alcoholC = C<sub>2</sub>H<sub>5</sub>O<sub>2</sub>, Glycerol (135)

Vol. % C in (B + C)	$\varphi_{25}$	$\varphi_{35}$
Pure solvents (B + C)		
0.0	176.9	204.6
25.0	51.0	65.0
50.0	10.8	15.7
75.0	1.65	2.82
100.0	0.158	0.340
(B + C) + 0.1N CoCl <sub>2</sub>		
0.0	157.1	181.6
25.0	44.5	57.6
50.0	9.26	13.4
75.0	1.35	2.40
100.0	0.133	0.297

B = C<sub>2</sub>H<sub>5</sub>O, Ethyl alcoholC = C<sub>2</sub>H<sub>5</sub>O<sub>2</sub>, Glycerol (135)

Wt. % C in (B + C)	$\varphi_{25}$	$\varphi_{35}$
Pure solvents (B + C)		
10	90.1	110.3
25	22.9	31.4
50	4.87	7.56
75	0.92	1.68
100	0.158	0.340
(B + C) + 0.1N CoCl <sub>2</sub>		
10	83.8	101.8
25	20.3	27.7
50	4.08	6.38
75	0.739	1.355
100	0.133	0.297

**Ca(NO<sub>3</sub>)<sub>2</sub>**B = CH<sub>3</sub>NO, FormamideC = C<sub>2</sub>H<sub>5</sub>O, Ethyl alcohol (63)

Wt. % C in (B + C)	$\varphi_{15}$	$\varphi_{25}$	$\varphi_{35}$
0M A/l			
25	29.66	38.60	48.22
50	40.40	51.71	63.82
0.1M A/l			
25	26.75	35.28	43.90
50	36.05	46.34	56.98

B = CH<sub>3</sub>O, Methyl alcoholC = C<sub>2</sub>H<sub>5</sub>O, Acetone (61)

Wt. % C in (B + C)	$\varphi_{25}$	$\varphi_{35}$
Pure solvents (B + C)		
0.0	122.2	176.7
25.0	153.9	216.7
50.0	187.4	257.0
75.0	222.2	290.1
100.0	244.1	308.9



B = CH<sub>3</sub>O; C = C<sub>2</sub>H<sub>5</sub>O.—

(Continued)

Wt. % C in (B + C)	(B + C) + 0.1N Ca(NO <sub>3</sub> ) <sub>2</sub>	(B + C) + 0.00016N Ca(NO <sub>3</sub> ) <sub>2</sub>
	$\varphi_{25}$	
0.0	161.8	180.4
25.0	188.0	217.2
50.0	220.6	254.7
75.0	255.6	287.3
100.0	282.1	307.3

## LiBr

B = CH<sub>3</sub>O, Methyl alcohol  
C = C<sub>2</sub>H<sub>5</sub>O, Acetone (67)

Wt. % C in (B + C)	$\varphi_0$	$\varphi_{25}$
	0M A/l	
0	122.20	176.70
25	153.90	216.70
50	187.40	257.10
75	222.20	290.10
100	244.10	308.90

0.000625M A/l

0	119.82	177.46
25		197.29
50	173.17	236.18
75		279.25
100	242.85	299.42

0.1M A/l

0	111.18	163.28
25		183.30
50		220.87
75		264.88
100	232.45	286.96

C = C<sub>2</sub>H<sub>5</sub>O<sub>3</sub>, Glycerol (135)

Vol. % C in (B + C)	$\varphi_{25}$	$\varphi_{35}$
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For pure solvents, v. A = CoCl<sub>2</sub>

(B + C) + 0.1N LiBr

0.0	164.0	188.5
25.0	47.5	60.7
50.0	9.88	14.4
75.0	1.53	2.63
100.0	0.147	0.313

B = C<sub>2</sub>H<sub>5</sub>O, Ethyl alcohol  
C = C<sub>2</sub>H<sub>5</sub>O, Acetone (67)

Wt. %C in (B + C)	$\varphi_0$	$\varphi_{25}$
	0M A/l	
0	53.9	90.4
25	96.1	148.9
50	147.0	205.2
75	200.4	264.8
100	244.1	308.9

0.000625M A/l

0	45.48	81.69
25		129.34
50		193.59
75		258.10
100	242.85	299.42

B = C<sub>2</sub>H<sub>5</sub>O; C = C<sub>2</sub>H<sub>5</sub>O.—

(Continued)

Wt. %C in (B + C)	$\varphi_0$	$\varphi_{25}$
	0.1M A/l	
0	40.96	73.18
25		121.69
50	136.0	180.05
75		235.99
100	232.45	286.96

C = C<sub>2</sub>H<sub>5</sub>O<sub>3</sub>, Glycerol (135)

Vol. % C in (B + C)	$\varphi_{25}$	$\varphi_{35}$
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For pure solvents, v. A = CoCl<sub>2</sub>

(B + C) + 0.1N LiBr

10	80.9	101.4
25	21.9	30.3
50	4.52	7.08
75	0.838	1.549
100	0.147	0.313

LiNO<sub>3</sub>B = CH<sub>3</sub>NO, Formamide  
C = C<sub>2</sub>H<sub>5</sub>O, Ethyl alcohol  
(63)

Wt. % C in (B + C)	$\varphi_{15}$	$\varphi_{25}$	$\varphi_{35}$
	0M A/l		
25	29.65	38.82	47.87
50	40.45	51.76	63.49
75	56.98	70.97	85.32
	0.1M A/l		
25	28.39	36.89	46.10
50	38.12	48.01	59.74
75	52.77	65.70	79.37
	0.25M A/l		
25	26.32	34.73	43.25
50	34.95	45.07	55.28
75	47.10	59.52	71.58

## KI

B = CH<sub>3</sub>O, Methyl alcohol  
C = C<sub>2</sub>H<sub>5</sub>O<sub>3</sub>, Glycerol (135)

Vol. % C in (B + C)	$\varphi_{25}$	$\varphi_{35}$
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For pure solvents, v. A = CoCl<sub>2</sub>

(B + C) + 0.1N KI

0.0	168.3	194.2
25.0	49.5	63.0
50.0	10.7	15.5
75.0	1.59	2.75
100.0	0.149	0.319

B = C<sub>2</sub>H<sub>5</sub>O, Ethyl alcohol  
C = C<sub>2</sub>H<sub>5</sub>O<sub>3</sub>, Glycerol (135)

Vol. % C in (B + C)	$\varphi_{25}$	$\varphi_{35}$
	For pure solvents, v. A = CoCl <sub>2</sub>	
	(B + C) + 0.1N KI	
10	85.0	104.2
25	22.1	30.4
50	4.86	7.54
75	0.909	1.66
100	0.149	0.319

## KCNS

B = CH<sub>3</sub>O, Methyl alcohol  
C = C<sub>2</sub>H<sub>5</sub>O, Ethyl alcohol (68)

Wt. %* C in (B + C)	$\varphi_0$	$\varphi_{25}$
	0M A/l	
0	110.7	165.4
25	99.7	147.3
50	79.4	124.9
75	61.8	105.5
100	47.4	87.4
	0.1M A/l	
0	104.2	157.4
25	94.5	140.6
50	74.6	120.9
75	58.6	101.1
100	44.7	79.3

C = C<sub>2</sub>H<sub>5</sub>O, Acetone (68)

Wt. %* C in (B + C)	$\varphi_0$	$\varphi_{25}$
	0M A/l	
0	110.7	165.4
25	153.9	196.6
50	193.1	222.3
75	230.5	240.6
100	198.2	251.5
	0.1M A/l	
0	104.2	157.4
25	134.6	185.9
50	177.6	202.7
75	211.6	219.0
100	188.9	242.4

B = C<sub>2</sub>H<sub>5</sub>O, Ethyl alcohol  
C = C<sub>2</sub>H<sub>5</sub>O, Acetone (68)

Wt. %* C in (B + C)	$\varphi_0$	$\varphi_{25}$
	0M A/l	
0	47.4	87.4
25	86.5	136.4
50	141.2	187.5

B = C<sub>2</sub>H<sub>5</sub>O; C = C<sub>2</sub>H<sub>5</sub>O.—

(Continued)

Wt. %* C in (B + C)	$\varphi_0$	$\varphi_{25}$
	0M A/l	
75	204.1	227.6
100	198.2	251.5
	0.000625M A/l	
0		83.5
25		131.3
50		186.0
75		224.5
100		249.4
	0.1M A/l	
0	44.7	79.3
25	76.8	128.1
50	126.0	165.9
75	186.8	214.4
100	188.9	242.4

## RbI

B = CH<sub>3</sub>NO, Formamide  
C = C<sub>2</sub>H<sub>5</sub>O, Ethyl alcohol  
(63)

Wt. %* C in (B + C)	$\varphi_{15}$	$\varphi_{25}$	$\varphi_{35}$
	0M A/l		
25	29.7	38.9	48.3
50	40.5	51.7	63.4
75	56.9	70.7	84.9
	0.1M A/l		
25	28.8	37.6	46.6
50	38.9	49.2	60.7
75	52.7	67.4	81.4
	0.25M A/l		
50	35.8	45.7	56.5
75	50.1	63.3	76.4

\* Wt. % = Wt. % C in (B + C).

## THE A-COMPONENT HAS KEY-FORMULA BEGINNING WITH 16

C-Table, the C-Arrangement (v. Vol. III, p. viii)

## TWO-COMPONENT SYSTEMS

CCl<sub>4</sub>B = CHCl<sub>3</sub> (99, 102)

50 Wt. % A

°C	$\varphi$
0	116.8
25	153.8
40	183.5
55	206.6

(99)

Wt. % A	$\varphi_{25}$
0.00	185.2
19.27	175.7
57.28	151.7
81.17	131.4
100.00	113.2

B = C<sub>2</sub>Cl<sub>4</sub>

Tetrachloroethylene (58)

0.0	107.6
20.3	113.2
33.6	120.4
50.3	122.4
67.0	123.5
80.1	122.5
100.0	119.2

B = C<sub>2</sub>H<sub>2</sub>Cl<sub>4</sub>, 1, 1, 2, 2-  
Tetrachloroethane (58)

Wt. % A	$\varphi_{25}$
0.0	107.6
20.0	101.5
33.33	98.3
50	90.4
66.67	82.0
80	72.8
100	61.9

B = C<sub>2</sub>H<sub>2</sub>I<sub>4</sub>; for data at 25, 35,  
and 50°C, v. (157)B = C<sub>2</sub>H<sub>5</sub>O, Ethyl alcohol  
(46)\*

Wt. % B	°C	$\varphi$
0.0	75.6	200.4
4.58	65.1	193.1
6.71	64.5	191.9
9.65	64.0	192.3
20.96	63.8	188.7
30.2	64.2	188.7
36.6	64.8	190.1

\* Paper also contains density data



**CCl<sub>4</sub>—(Continued)****B = C<sub>2</sub>H<sub>5</sub>O—(Continued)**

Wt. % B	°C	φ
58.8	67.7	196.1
73.0	70.5	204.1
100.0	77.1	226.2

**B = C<sub>3</sub>H<sub>8</sub>O, Acetone (124, 125)**

M % B	φ <sub>0</sub>
0.00	75.2
11.40	87.8
36.44	117.4
51.18	136.2
73.55	177.9
86.53	210.1
96.67	237.5
100.00	250.0

M % B	φ <sub>0</sub>	φ <sub>20</sub>	φ <sub>40</sub>
(145)			
0.0	138	173	204
17.6	137	171	205
39.1	145	183	218
51.7	154	196	235
63.8	176	215	254
84.3	204	258	301
100.0	247	293	355

M % B	φ <sub>-15</sub> (43)	φ <sub>0</sub> (43)
0	117	140
10	112	135
20	110	134
30	109	138
60	123	166
100	222	253

See also (157) for data at 18, 30 and 40°C

Wt. % B	°C (46)*	φ
0.00	60.2	256.5
6.79	62.0	263.2
12.20	62.8	272.5
27.4	63.0	296.7
36.1	62.1	312.5
53.5	60.0	346.0
59.6	59.2	355.9
68.7	58.2	375.9
80.4	57.1	387.6
100.0	55.4	420.2

\* Paper also contains density data.

**B = C<sub>4</sub>H<sub>8</sub>O<sub>2</sub>, Ethyl acetate; for data at 15, 35, and 50°C, v. (157).**

Wt. % B	°C (46)*	φ
0.0	75.4	201.2
10.9	75.5	216.9
22.8	75.8	234.7
46.1	76.4	259.1
53.8	76.7	266.7
73.4	77.6	289.0
100.0	79.3	315.5

Wt. % B	°C (46)*	φ
0.0	75.4	201.2
10.9	75.5	216.9
22.8	75.8	234.7
46.1	76.4	259.1
53.8	76.7	266.7
73.4	77.6	289.0
100.0	79.3	315.5

\* Paper also contains density data.

**B = C<sub>6</sub>H<sub>6</sub>—(Continued)**

Wt. % B	φ <sub>25</sub> (99)
0.00	113.2
13.73	123.8
40.78	141.6
58.60	151.5
100.00	166.9

Wt. % B	φ <sub>0</sub>	φ <sub>10</sub>	φ <sub>20</sub>
(141)			
0.00	74.1	88.2	103.2
22.37	83.6	100.0	117.6
43.79	91.9	110.1	128.9
67.71	100.6	120.2	141.4
100.00	110.8	131.5	154.1

Wt. % B	φ <sub>30</sub>	φ <sub>40</sub>	φ <sub>50</sub>
0.00	118.9	135.1	153.0
22.37	136.2	156.0	176.7
43.79	149.0	171.5	194.9
67.71	163.4	186.6	211.4
100.00	178.0	203.1	228.8

**B = C<sub>10</sub>H<sub>8</sub>, Naphthalene; for data from 15 to 31°C, v. (74.1).**

Wt. % A	φ <sub>0</sub>	φ <sub>10</sub>	φ <sub>20</sub>
(141)			
0.00	168.3	186.6	205.3
21.60	193.1	211.4	230.9
38.81	207.5	225.7	243.9
48.11	213.2		248.1
63.81	222.7	242.1	261.8
82.39	228.3	248.1	268.1
100.00	232.8	253.0	272.5

Wt. % B	φ <sub>25</sub>
0.00	273.5
18.07	203.0
26.50	182.9
30.05	176.3
47.18	150.2
60.50	131.2
67.69	118.9
74.36	110.3
80.71	104.9
83.09	105.8
100.00	89.8

**B = C<sub>3</sub>H<sub>8</sub>O, Acetone (43); v. also (157)**

M % B	φ <sub>-15</sub>	φ <sub>-10</sub>	φ <sub>0</sub>
0	194.6	202.0	227.3
40	218.8	226.2	247.5
60	222.2	241.5	253.8
80	216.9	228.3	254.5
100	206.6	222.2	250.0

**B = C<sub>4</sub>H<sub>8</sub>O<sub>2</sub>, Ethyl acetate (99)**

Wt. % B	φ <sub>25</sub>
0.00	279.3
16.40	272.5
39.25	257.1
66.41	240.4
100.00	216.5

**B = C<sub>4</sub>H<sub>10</sub>O, Ethyl ether (99)**

Wt. % B	φ <sub>25</sub>
0.00	279.3
13.10	295.9
34.37	326.8
62.76	371.7
100.00	434.8

**B = C<sub>6</sub>H<sub>6</sub>, Benzene (99)**

Wt. % B	φ <sub>25</sub>
0.00	279.3
8.87	266.0
34.86	224.2
75.89	183.8
100.00	166.9

**B = C<sub>7</sub>H<sub>8</sub>, Toluene (99)**

Wt. % B	φ <sub>25</sub>
0.00	279.3
7.27	270.3
39.99	239.8
63.24	213.2
100.00	184.8

**CHBr<sub>3</sub>  
B = CH<sub>3</sub>O, Methyl alcohol (111)**

M A/l	φ <sub>20</sub>
0.25	162
0.5	156
1.0	143

**B = C<sub>2</sub>H<sub>5</sub>O, Ethyl alcohol (110)**

Wt. % B	φ <sub>25</sub>
0.25	79.84
0.5	77.10
1.0	75.87

**B = C<sub>3</sub>H<sub>8</sub>O, Acetone (111)**

Wt. % B	φ <sub>25</sub>
0.25	286.6
1.0	246.0

**B = C<sub>3</sub>H<sub>7</sub>O, Propyl alcohol (111)**

Wt. % B	φ <sub>25</sub>
1.0	44.2

**B = C<sub>4</sub>H<sub>10</sub>O, Ethyl ether (111)**

Wt. % B	φ <sub>25</sub>
1.0	290.7

**B = C<sub>5</sub>H<sub>12</sub>O, Isoamyl alcohol (111)**

M A/l	φ <sub>20</sub>
1.0	24.59

**B = C<sub>6</sub>H<sub>5</sub>NO<sub>2</sub>, Nitrobenzene (26)**

Wt. % B	φ <sub>10</sub>	φ <sub>70-5</sub>
0.00	45.1	99.1
9.68	44.4	103.7
25.85	42.3	106.2
50.08	40.3	110.6
65.83	40.3	113.5
88.39	41.0	117.0
100.00	41.5	117.3

**B = C<sub>6</sub>H<sub>6</sub>, Benzene (111)**

M A/l	φ <sub>20</sub>
1.0	135.4

**CHCl<sub>3</sub>****B = C<sub>2</sub>H<sub>5</sub>O, Ethyl alcohol (52)**

Wt. % B	°C	φ
0.0	60.2	250.6
5.78	58.5	250.0
10.05	58.4	247.5
10.91	58.5	246.3
24.02	59.8	227.3
35.28	61.5	224.2
44.7	63.5	216.5
56.1	66.4	213.7
68.8	69.8	214.1
83.6	73.4	218.8
100.0	77.1	226.2

M A/l	φ <sub>20</sub> (46, 110)
0.25	102.3
0.5	102.6
1.0	105.4

**B = C<sub>3</sub>H<sub>8</sub>O, Acetone (157)****B = C<sub>4</sub>H<sub>10</sub>O, Ethyl ether (141)**

Wt. % B	φ <sub>0</sub>	φ <sub>10</sub>
0.00	142.9	159.8
15.94	147.5	168.1
40.14	177.9	204.5
59.80	227.2	257.7
79.30	285.7	320.5
100.00	349.6	387.2

**B = C<sub>4</sub>H<sub>11</sub>ClN, Diethylammonium chloride (150)**

M B/l	φ <sub>25</sub>
0.0	171.8
0.1	165.3
0.4	149.7

**B = C<sub>4</sub>H<sub>11</sub>N<sub>2</sub>O<sub>3</sub>, Diethylammonium nitrate (150, 151)**

Wt. % B	φ <sub>25</sub>
0.4	142.4



**B = C<sub>6</sub>H<sub>5</sub>Br, Bromobenzene**  
(124, 125)

M % B	$\varphi_0$
0.00	142.9
8.48	133.0
23.54	116.6
40.17	98.5
64.69	83.5
86.86	72.5
100.00	68.0

**B = C<sub>6</sub>H<sub>6</sub>, Benzene (99)**

Wt. % B	$\varphi_{25}$
0.00	185.2
6.97	183.2
23.01	179.5
72.78	172.1
85.83	170.4
100.00	166.9

**50 Wt. % B (102)**

°C	$\varphi$
0	127.2
25	176.2
40	210.5
55	241.8
70	275.9

**B = C<sub>6</sub>H<sub>12</sub>, Cyclohexane; for data at 20°C, v. (152.2).****B = C<sub>6</sub>H<sub>15</sub>ClN, Triethylammonium chloride (150)**

M B/l	$\varphi_{25}$
0.1	163.4
0.2	159.2

**B = C<sub>6</sub>H<sub>5</sub>O, Acetophenone (126)**

M % B	$\varphi_{25}$
0.00	181.8
9.92	152.7
33.70	109.3
50.10	90.3
71.25	74.0
88.75	65.4
100.00	60.8

**B = C<sub>6</sub>H<sub>10</sub>O, Phenetole (126)**

M % B	$\varphi_0$
0.00	142.9
9.09	123.8
32.38	96.2
48.18	84.5
80.09	62.4
100.00	53.1

**B = C<sub>8</sub>H<sub>17</sub>BrN, Tetraethylammonium bromide (151)**

Wt. % B	$\varphi_{25}$
0.00	173.6
6.12	101.8
7.48	92.4

**B = C<sub>8</sub>H<sub>17</sub>ClN, Tetraethylammonium chloride (150, 151)**  
 $\varphi_{25} = 159.7$  for M B/l = 0.1.**B = C<sub>10</sub>H<sub>8</sub>, Naphthalene; for data from 6 to 20°C, v. (74.1).****B = C<sub>10</sub>H<sub>12</sub>, Tetrahydronaphthalene; for data at 20°C, v. (152.2).****B = C<sub>10</sub>H<sub>12</sub>O, Anethole; for data at 20°C, v. (152.2).****B = C<sub>10</sub>H<sub>24</sub>ClN, Diisoamylammonium chloride (150, 151)**  
 $\varphi_{25} = 160.0$  for M B/l = 0.2.**B = C<sub>12</sub>H<sub>10</sub>O, Phenyl ether (124, 125)**

M % B	$\varphi_{25}$
0.00	185.9
18.30	120.5
43.04	71.9
68.64	45.0
100.00	27.3

**B = C<sub>16</sub>H<sub>20</sub>N<sub>2</sub>O, Camphorquinone  $\alpha$ - ( $\beta$ -)phenylhydrazine (137)**

M B/kg	$\varphi_{24.7}$
0.25	157.9 ( $\beta$ )
0.25	150.7 ( $\alpha$ )

**CH<sub>2</sub>Cl<sub>2</sub>****Methylene chloride****B = C<sub>3</sub>H<sub>6</sub>O, Acetone (126)**

M % B	$\varphi_0$
0.00	184.2
12.76	186.9
42.35	198.4
60.46	210.5
81.12	226.2
92.27	239.2
100.00	250.0

**CH<sub>2</sub>O<sub>2</sub>****Formic acid****B = CH<sub>3</sub>NO, Formamide (103)**

M % B	$\varphi_{25}$	$\varphi_{40}$
0.00	62.5	83.3
10.00	51.4	70.0
20.05	43.2	59.3
30.15	39.1	54.1
40.00	35.1	48.4
50.02	32.7	44.8
60.01	31.3	43.3
70.00	30.4	42.7
80.01	30.2	42.5
90.00	29.9	42.2
100.00	29.8	42.0

**B = CH<sub>3</sub>NO<sub>2</sub>, Ammonium formate (134)**

M B/l	$\varphi_{25}$
0.00	61.7
0.05978	59.5
0.1422	57.3
0.2868	53.8
0.3207	53.0
0.3676	52.0
0.5221	48.5
0.8290	42.5
0.8847	41.3

**B = C<sub>2</sub>H<sub>4</sub>O<sub>2</sub>, Acetic acid (21)**

Wt. % B	$\varphi_{15}$	$\varphi_{25}$
0	50.9	63.6
10	50.8	63.2
20	50.0	62.2
30	49.7	62.2
40	50.4	63.0
50	51.5	63.9
60	53.1	66.4
70	55.8	68.4
80	58.8	71.9
90	64.2	77.8
100	70.9	85.2

**Wt. % B**

0.0	46.8
22.7	44.8
50.0	43.5
68.7	41.9
100.0	39.6

**B = C<sub>7</sub>H<sub>5</sub>NO<sub>2</sub>, Aniline formate (134)**

M B/l	$\varphi_{25}$
0.08122	58.7
0.1587	56.3
0.3316	51.5
0.4070	50.0
0.6276	44.8
1.0410	36.5

**CH<sub>3</sub>NO****Formamide****B = CH<sub>3</sub>NO<sub>2</sub>, Ammonium formate (63)**

M B/l	$\varphi_{15}$	$\varphi_{25}$	$\varphi_{35}$
0.0	22.8	30.0	37.9
0.1	22.2	29.4	36.8
0.25	21.1	28.2	35.4

**B = C<sub>2</sub>H<sub>4</sub>O<sub>2</sub>, Acetic acid (103)**

M % B	$\varphi_{25}$	$\varphi_{40}$
0.0	29.8	42.0
9.62	26.1	38.6
20.39	24.1	34.5
29.74	23.2	34.4
40.56	23.0	34.4
49.82	23.7	35.8
59.89	25.9	38.6
69.42	28.7	42.3
78.95	35.0	49.3
89.10	50.0	68.4
100.00	78.1	101.3

**B = C<sub>2</sub>H<sub>5</sub>O, Ethyl alcohol (103)**

M % B	$\varphi_{25}$	$\varphi_{40}$
0.00	29.8	42.0
10.00	32.7	46.0
18.92	35.9	50.3
29.76	39.8	55.6
39.29	44.3	61.6
50.09	49.7	68.3
59.29	55.1	75.8
69.86	64.0	87.3
80.09	72.7	98.4
89.95	81.4	109.2
100.00	92.1	121.8

v. also p. 31, A = LiNO<sub>3</sub>**B = C<sub>3</sub>H<sub>7</sub>O<sub>2</sub>, Propionic acid (103)**

M % B	$\varphi_{25}$	$\varphi_{40}$
0.0	29.8	42.0
2.40	26.1	28.2
8.99	17.9	22.3
18.85	14.4	
26.62	13.9	21.2
40.13	14.3	22.1
50.24	15.4	24.0
60.21	17.6	28.2
70.08	22.5	34.8
80.51	29.7	44.8
89.98	46.5	65.8
100.00	96.6	118.6

**B = C<sub>3</sub>H<sub>7</sub>O, Propyl alcohol (42)**

Wt. % B	$\varphi_{25}$
0.00	30.3
11.23	30.6
20.67	30.9
29.94	32.0
39.96	33.5
49.99	35.8
59.99	38.1
69.99	41.7
79.97	45.0
90.03	50.3
94.55	51.7
100.00	51.9

**B = C<sub>4</sub>H<sub>7</sub>O<sub>2</sub>, n-Butyric acid (103)**

M % B	$\varphi_{25}$	$\varphi_{40}$
0.00	29.8	42.0
4.90	20.0	30.7
14.30	13.6	20.9
20.10	11.7	18.0
29.89	10.9	17.2
40.04	10.7	17.2
49.73	11.9	18.6
59.69	14.1	22.4
69.87	19.1	28.9
79.56	28.3	39.0
89.57	42.9	57.7
100.00	64.3	81.5

**B = C<sub>4</sub>H<sub>9</sub>O, Isobutyl alcohol (42)**

Wt. % B	$\varphi_{25}$
10.09	28.7
19.95	27.1
30.00	26.6
39.81	25.9
49.98	26.2
59.88	27.1
69.84	28.4
80.02	30.2
89.96	31.8
95.00	31.9
100.00	29.7

**B = C<sub>4</sub>H<sub>11</sub>ClN, Tetramethylammonium chloride (23, 64)**

M B/l	$\varphi_{15}$	$\varphi_{25}$	$\varphi_{35}$
0.0	23.4	31.3	39.8
0.1	22.8	30.2	38.4
0.25	22.2	29.2	37.3
0.5	20.9	28.0	35.8



**CH<sub>3</sub>NO.—(Continued)**B = C<sub>5</sub>H<sub>5</sub>N, Pyridine (33)

Wt. % B	$\varphi_{25}$
82.88	73.3
88.90	86.2
92.23	94.0

B = C<sub>5</sub>H<sub>12</sub>O, Isoamyl alcohol (26)

Wt. % B	$\varphi_0$	$\varphi_{76.5}$
0.00	13.24	79.7
10.38	11.66	77.4
30.14	9.40	75.7
49.84	9.00	76.3
69.92	10.08	84.9
90.01	11.96	99.5
97.18	11.79	103.5
100.00	11.32	105.2

Wt. % B (42)	$\varphi_{25}$
10.01	28.03
19.94	26.32
29.98	24.56
39.95	23.52
50.01	23.40
60.00	23.96
69.98	25.04
79.95	26.33
84.92	27.11
89.86	28.00
95.01	27.94
100.00	26.33

B = C<sub>5</sub>H<sub>10</sub>NI, Tetraethylammonium iodide (23, 64)

M B/l	$\varphi_{15}$	$\varphi_{25}$	$\varphi_{35}$
0.0	23.3	30.7	39.0
0.1	22.6	30.0	38.4
0.25	21.9	28.7	37.2
0.5	20.5	27.6	35.7

**CH<sub>4</sub>N<sub>2</sub>O**

Urea

B = CH<sub>3</sub>O, Methyl alcohol (143)

g A/kg B	$\varphi_{25}$	$\varphi_{40}$
0.0	181.1	224.2
8.693	176.5	219.4
15.67	173.3	214.5
29.86	167.6	207.5
43.35	161.7	201.5
61.10	155.4	194.0
91.54	149.5	182.1

B = CH<sub>3</sub>N, Methylamine (48)

M A/l	$\varphi_0$
0.93	326.2
1.75	253.2
3.33	156.8

B = C<sub>2</sub>H<sub>5</sub>O, Ethyl alcohol (143); cf. (51.5)

M % B	$\varphi_{25}$	$\varphi_{40}$
95.465	80.5	128.8
96.934	83.7	132.7
98.588	87.7	137.0
99.266	89.2	139.6
100.000	91.1	142.1

**B = C<sub>2</sub>H<sub>5</sub>O.—(Continued)**

M % B	$\varphi_{40}$
95.352	104.2
96.335	107.2
97.083	109.6
98.197	113.1
98.917	115.6
99.339	117.1
99.630	118.6
100.000	119.3

B = C<sub>5</sub>H<sub>5</sub>N, Pyridine (33)

Wt. % B	$\varphi_{25}$
99.09	106.5

**CH<sub>4</sub>N<sub>2</sub>S**

Thiourea

B = C<sub>5</sub>H<sub>5</sub>N, Pyridine (33)

Wt. % B	$\varphi_{25}$
87.43	49.5
94.48	79.9

**CH<sub>4</sub>O**

Methyl alcohol

B = C<sub>2</sub>H<sub>5</sub>I, Ethyl iodide (145)

Wt. % B	$\varphi_{20}$
0.0	167.4
31.3	164.8
73.2	158.2
100.0	154.8

For data at 20, 35, and 45°C, v. (157).

B = C<sub>2</sub>H<sub>5</sub>O, Ethyl alcohol (55)

Wt. % B	$\varphi_{25}$
0.00	177.9
8.75	170.6
15.23	165.3
19.31	161.9
58.98	126.8
89.6	101.6
95.63	95.5
100.00	91.6

Wt. % B (16)	Vol. % B, 25°C	$\varphi_{25}$	$\varphi_{35}$
0.00	0.0	182.4	209.9
26.16	26.23	156.6	181.1
49.60	49.78	135.6	157.4
73.85	74.15	113.6	134.0
100.00	100.0	91.0	109.1

Wt. % B	$\varphi_{45}$	$\varphi_{55}$	$\varphi_{65}$
0.00	238.0	269.5	
26.16	207.9	236.3	
49.60	182.4	210.1	241.2
73.85	157.3	183.2	
100.00	130.6	155.0	181.5

v. also p. 31, A = KCN

B = C<sub>2</sub>H<sub>5</sub>O, Acetone (61, 66)

Vol. % B	$\varphi_0$	$\varphi_{25}$
0	116.7	171.6
25	136.2	193.2
50	167.8	231.0
75	212.3	270.1
100	233.2	288.9

v. also p. 31, A = LiBr

B = C<sub>3</sub>H<sub>7</sub>O, Propyl alcohol (55)

Wt. % B	$\varphi_{25}$
0.0	177.9
11.1	164.5
23.8	140.9
65.2	93.1
91.8	61.1
93.75	56.4
96.6	54.2
100.0	52.2

B = C<sub>3</sub>H<sub>8</sub>O<sub>3</sub>, Glycerol v. p. 30, A = NH<sub>4</sub>Br and A = CoCl<sub>2</sub>.

Wt. % B	$\varphi_{25}$
3.70	165.5
7.20	148.1

B = C<sub>4</sub>H<sub>4</sub>O<sub>4</sub>, Fumaric acid (60); cf. (137)

Wt. % B	$\varphi_{25}$
3.35	166.0
8.15	143.1

B = C<sub>4</sub>H<sub>4</sub>O<sub>4</sub>, Maleic acid (137)B = C<sub>4</sub>H<sub>4</sub>O<sub>4</sub>, Succinic acid (60)

Wt. % B	$\varphi_{25}$
0.00	181.5
3.62	165.9
5.96	152.3
10.08	135.6

B = C<sub>4</sub>H<sub>10</sub>O, Ethyl ether (5)

Wt. % B	$\varphi_{25}$
0.00	181.6
23.12	211.2
35.07	232.7
47.40	260.0
60.23	296.0
73.08	338.6
86.33	391.7
100.00	442.5

 $\varphi_{25} = 260.1$  at 50 Vol. % B (6).B = C<sub>5</sub>H<sub>8</sub>O<sub>4</sub>, Citraconic acid (137)B = C<sub>5</sub>H<sub>8</sub>O<sub>4</sub>, Mesaconic acid (137)B = C<sub>6</sub>H<sub>5</sub>NO<sub>2</sub>, Nitrobenzene (47)

Vol. % B	$\varphi_{25}$
0	178.3
25	147.8
50	116.7
75	87.3
100	55.2

B = C<sub>6</sub>H<sub>6</sub>, Benzene

Vol. % B	$\varphi_{25}$ (17)	$\varphi_{25}$ (48)
0	178.4	178.4
25	177.3	177.2
50	176.0	176.0
75	174.7	174.7
100	173.7	173.7

Wt. % B	$\varphi_{25}$ (46)*	$\varphi$
0.00	63.7	306.7
18.14	59.9	288.2
31.60	58.2	282.5
41.60	57.6	278.6

**B = C<sub>6</sub>H<sub>6</sub>.—(Continued)**

Wt. % B	$\varphi_{25}$	$\varphi$
50.1	57.4	278.6
63.3	57.2	277.0
70.4	57.3	277.8
78.5	57.6	276.2
90.4	59.0	276.2
91.9	59.6	278.6
100.0	79.3	315.5

\* Paper also contains density data.

B = C<sub>7</sub>H<sub>8</sub>O, Anisole (5)

Vol. % B	$\varphi_{25}$
50	141.8 (6)
Wt. % B	$\varphi_{25}$
0.00	180.5
15.11	170.5
29.40	160.6
42.91	151.0
55.60	141.4
67.62	130.5
79.00	123.5
89.73	112.9
100.00	99.0

B = C<sub>8</sub>H<sub>10</sub>O, Phenetole (5)

Wt. % B	$\varphi_{25}$
0.00	180.6
14.83	167.9
28.93	156.1
42.24	143.8
54.88	132.1
67.00	122.6
78.57	111.9
100.00	87.6

B = C<sub>9</sub>H<sub>8</sub>O<sub>2</sub>, Phenylpropionic acid (60)

Wt. % B	$\varphi_{25}$
5.21	163.5
10.35	147.3

B = C<sub>9</sub>H<sub>8</sub>O<sub>2</sub>, Cinnamic acid (60)

Wt. % B	$\varphi_{25}$
6.25	157.8
9.24	151.0
11.06	143.7

B = C<sub>9</sub>H<sub>10</sub>O<sub>2</sub>,  $\beta$ -Phenylpropionic acid (60)

Wt. % B	$\varphi_{25}$
4.66	167.5
9.32	151.8

B = C<sub>10</sub>H<sub>8</sub>O,  $\alpha$ -Naphthol; for data at 20°C, v. (152.2).B = C<sub>10</sub>H<sub>12</sub>, 1,2,3,4-Tetrahydronaphthalene (59)

Wt. % B	$\varphi_{25}$
0.00	178.3
5.10	170.7
14.15	160.6
23.79	148.9
(50.6)	110.4

B = C<sub>14</sub>H<sub>10</sub>O<sub>2</sub>, Benzil (143)

g B/kg A	$\varphi_{15}$
0.00	158.9
10.94	156.0
18.89	154.3
31.12	151.8
42.93	150.1



B = C<sub>14</sub>H<sub>10</sub>O<sub>2</sub>.—(Continued)

g B/kg A	$\varphi_{40}$
10.74	219.7
20.10	216.3
33.37	211.6
54.77	204.9

CH<sub>3</sub>N

## Methylamine

B = C<sub>6</sub>H<sub>5</sub>N<sub>2</sub>O<sub>4</sub>, 1, 2, 4-Dinitroaniline (48)

M B/l	$\varphi_0$
0.161	390.6
0.240	371.3
0.356	339.1
0.512	312.1
0.666	282.0

B = C<sub>7</sub>H<sub>5</sub>NO<sub>3</sub>S, *m*-Methoxybenzenesulfonamide (48)

M B/l	$\varphi_0$
1.27	177.6
1.35	175.5
2.01	90.2
3.76	8.01

B = C<sub>12</sub>H<sub>22</sub>O<sub>11</sub>, Sucrose (48)

	$\varphi_0$
0.97	29.65
1.44	2.24

C<sub>2</sub>HCl<sub>3</sub>

## Trichloroethylene

B = C<sub>2</sub>HCl<sub>3</sub>, Pentachloroethane (55, 58)

Wt. % A	$\varphi_{25}$
0.0	46.1
17.9	69.5
30.4	86.3
46.5	105.3
63.5	130.7
77.7	150.8
100.0	182.2

C<sub>2</sub>HCl<sub>3</sub>O

## Chloral

B = C<sub>2</sub>H<sub>5</sub>O, Ethyl alcohol (82)

Wt. % A	$\varphi_{40}$	$\varphi_{45}$
0.0	125.6	138.9
26.24	88.8	97.0
36.16	71.1	78.7
44.46	57.0	63.7
51.63	45.45	51.2
57.85	35.90	42.03
68.10	24.67	29.7
70.29	22.98	27.93
72.37	21.59	26.54
74.34	21.01	25.93
75.47	21.26	26.40
76.20	21.91	27.23
79.65	25.40	31.24
82.76	30.20	36.54
88.20	44.29	50.28
90.48	50.61	58.00
92.76	56.98	64.85
96.64	74.02	82.03
100.0	99.11	107.07
Wt. % A	$\varphi_{60}$	$\varphi_{65}$
0.0	152.21	179.9
26.24	106.50	126.74
36.16	87.64	105.71

B = C<sub>3</sub>H<sub>5</sub>O.—(Continued)

Wt. % A	$\varphi_{50}$	$\varphi_{60}$
44.46	71.58	88.42
51.63	58.75	74.74
57.85	48.2	62.7
68.10	35.1	47.2
70.29	33.3	44.9
72.37	31.8	43.9
74.34	31.2	43.2
75.47	31.8	43.4
76.20	32.6	45.1
79.65	37.0	48.9
82.76	41.8	54.5
88.20	56.9	70.2
90.48	65.4	79.9
92.76	72.5	86.8
96.64	89.3	104.1
100.0	115.1	128.4

Wt. % A	$\varphi_{70}$	$\varphi_{85}$
0.0	206.2	
26.24	151.7	209.6
36.16	128.2	173.6
44.46	107.6	144.9
51.63	92.4	123.9
57.85	79.2	108.5
68.10	62.5	90.5
70.29	57.4	86.0
72.37	58.2	84.0
74.34	58.6	84.3
75.47	58.6	85.5
76.20	59.5	85.6
79.65	63.8	90.8
82.76	69.0	97.9
88.20	85.9	119.3
90.48	96.1	125.0
92.76	103.5	135.3
96.64	120.9	
100.0	147.7	179.5

°C |  $\varphi$  (82, 83)

74.3 Wt. % A	
40	21.02
45	25.95

50 Wt. % A

50	
50	31.24
60	43.20
70	58.65
85	84.32

M A/l |  $\varphi_{90}$  (110)

0.25	
0.25	74.9
0.5	69.7
1.0	62.3

B = C<sub>5</sub>H<sub>11</sub>O, *tert*-Amyl alcohol (38)

M % B	$\varphi_{25}$	$\varphi_{40}$	$\varphi_{60}$
0	79.18	99.11	123.6
10	51.50	61.24	76.3
20	34.14	49.61	62.5
25	26.17	41.44	54.7
30	19.93	33.79	47.3
40	13.53	26.79	39.4
45	11.75	24.71	37.3
50	11.12	23.66	37.9
52.5	11.13	23.62	35.6
55	11.24	23.85	35.8
57.5	11.35	24.02	36.3
60	11.66	24.61	38.1

B = C<sub>5</sub>H<sub>11</sub>O.—(Continued)

M % B	$\varphi_{25}$	$\varphi_{40}$	$\varphi_{60}$
70	14.53	28.55	42.9
80	19.27	36.42	52.4
90	26.26	46.69	66.1
100	27.05	50.63	71.4

M % B	$\varphi_{70}$	$\varphi_{85}$
0	147.7	181.5
10	112.2	142.6
20	96.1	125.3
25	91.1	
30	88.3	
40	77.9	111.4
45	74.3	109.8
50	53.1	108.1
52.5	72.0	107.8
55	71.9	107.8
57.5	72.5	106.6
60	75.0	107.6
70	81.8	119.5
80	96.0	136.4
90	113.5	177.9
100	125.3	174.5

C<sub>2</sub>HCl<sub>3</sub>O<sub>2</sub>

## Trichloroacetic acid

B = C<sub>2</sub>H<sub>4</sub>O<sub>3</sub>, Acetic acid (70)

M % A	$\varphi_{25}$
0.00	89.2
7.37	65.3
17.77	44.9
32.09	29.74
43.48	23.00
52.62	19.32
58.53	17.06
65.81	14.59
100.00	(14.64)

B = C<sub>2</sub>H<sub>5</sub>O, Acetone (70)

M % B	$\varphi_{25}$
0.00	(14.6)
28.25	17.2
40.29	26.1
49.52	38.9
61.74	69.8
74.57	122.6
86.84	206.0
95.16	271.7
100.00	326.3

B = C<sub>2</sub>H<sub>5</sub>O<sub>2</sub>, Ethyl acetate (70)

	(14.64)
0.00	(14.64)
29.92	21.23
38.58	28.84
51.22	45.95
61.54	69.0
71.93	99.9
81.60	136.8
88.82	170.2
100.00	236.0

B = C<sub>2</sub>H<sub>5</sub>O, Acetophenone (70)

	(14.64)
0.00	(14.64)
31.85	8.97
42.06	10.72
51.24	13.58
59.10	18.05

B = C<sub>5</sub>H<sub>5</sub>O.—(Continued)

M % B	$\varphi_{25}$
70.61	26.78
78.79	34.12
86.00	41.64
91.04	47.35
100.00	59.49

B = C<sub>4</sub>H<sub>10</sub>O, Ethyl ether (146)

Wt. % B	$\varphi_{18}$
25.40	34.06
37.37	70.13
57.24	164.2
68.82	225.5
82.37	306.6
100.00	417.9

B = C<sub>5</sub>H<sub>10</sub>O<sub>2</sub>, Ethyl benzoate (70)

M % B	$\varphi_{25}$
0.00	(14.64)
32.42	11.94
42.05	14.15
50.93	17.10
60.18	21.69
68.75	26.94
79.04	34.13
91.13	43.03
100.00	50.46

C<sub>2</sub>HCl<sub>3</sub>

## Pentachloroethane

B = C<sub>2</sub>H<sub>5</sub>O, Acetone (126)

0.00	44.3
14.76	51.8
31.78	65.8
51.03	89.3
70.37	148.9
90.68	239.8
100.00	320.5

B = C<sub>2</sub>H<sub>5</sub>O, Ethyl ether (126)

M % B	$\varphi_0$
0.00	26.8
13.03	34.0
30.47	48.7
49.68	77.4
74.73	158.7
85.76	224.2
100.00	347.2

B = C<sub>2</sub>H<sub>5</sub>O, Acetophenone (126)

M % B	$\varphi_{25}$
0.00	44.3
11.63	42.7
32.95	42.4
53.38	44.3
73.13	49.3
89.74	55.6
100.00	60.8

B = C<sub>2</sub>H<sub>5</sub>O, Phenetole (126)

0.00	44.3
9.71	47.6
22.14	52.1
48.95	62.2
67.98	71.8
90.30	82.9
100.00	89.1



**C<sub>2</sub>HCl<sub>5</sub>—(Continued)**B = C<sub>12</sub>H<sub>10</sub>O, Phenyl ether  
(126)

M % B	$\varphi_{25}$
0.00	44.3
26.42	37.9
51.09	33.7
76.11	29.8
100.00	27.3

**C<sub>2</sub>H<sub>2</sub>Cl<sub>4</sub>**1, 1, 2, 2-Tetrachloroethane  
B = C<sub>3</sub>H<sub>6</sub>O, Acetone (126)

M % B	$\varphi_0$
0.00	36.1
15.92	43.9
58.07	80.6?
73.08	116.2
81.36	143.9
97.28	229.4
100.00	250

B = C<sub>4</sub>H<sub>10</sub>O, Ethyl ether (126)

M % B	$\varphi_0$
0.00	36.1
21.15	54.3
47.99	88.5
69.81	147.7
82.68	198.8?
94.01	296.7
100.00	347.2

B = C<sub>6</sub>H<sub>5</sub>NO<sub>2</sub>, Nitrobenzene  
(26)

Wt. % B	$\varphi_5$	$\varphi_{76.5}$
0.00	43.6	129.0
10.00	39.4	121.4
30.05	34.2	117.1
48.33	33.3	111.8
69.26	34.4	113.5
89.64	36.0	
100.00	37.1	117.0

B = C<sub>8</sub>H<sub>8</sub>O, Acetophenone  
(126)

M % B	$\varphi_{25}$
0.00	119.3
12.55	112.0
32.15	97.8
53.97	83.5
73.29	72.4
91.42	64.3
100.00	60.8

Wt. % B	$\varphi_{10}$ (26)
0.00	48.5
10.19	42.4
30.07	36.0
50.00	35.2
70.01	37.6
90.00	41.6
100.00	44.0

Wt. % B	$\varphi_{20}$ (26)
0.00	131.1
10.02	126.7
31.20	119.6
69.93	123.6
89.74	132.3
100.00	136.2

B = C<sub>8</sub>H<sub>10</sub>O, Phenetole (123)

M % B	$\varphi_0$
0.00	36.1
21.76	39.2
51.67	41.5
62.80	44.0
78.37	47.6
100.00	53.1

**C<sub>2</sub>H<sub>3</sub>N**

Acetonitrile

B = C<sub>5</sub>H<sub>5</sub>N, Pyridine (123)

Vol. % B	$\varphi_{25}$
0.0	278.6
66.7	172.1

**C<sub>2</sub>H<sub>4</sub>Br<sub>2</sub>**

Ethylene bromide

B = C<sub>3</sub>H<sub>6</sub>Br<sub>2</sub>, 1, 2-Dibromopropane; for data at 17, 40, and 85°C, v. (157).B = C<sub>12</sub>H<sub>18</sub>O<sub>8</sub>, Diethyl diacetyltartrate (132)

Wt. % B	$\varphi_{87.3}$	$\varphi_{82.2}$	$\varphi_{99}$
0.00	108.5	133.3	154.3
8.43	76.6?	94.5?	108.6?
21.62	96.0?	119.8?	153.6?
53.79	28.02?	42.14?	58.7?
76.58	23.26	36.32	56.5
92.34	14.24	24.41	40.96
100.00	11.17	18.17	32.0

**C<sub>2</sub>H<sub>4</sub>Cl<sub>2</sub>**

Ethylene chloride

B = C<sub>6</sub>H<sub>6</sub>, Benzene (43); cf. also (157)

M % B	$\varphi_0$	$\varphi_{19.4}$	$\varphi_{50}$
0	92.9	125.0	177.0
30	107.2	144.9	203.3
50	115.2	155.0	219.8
70	119.8	161.3	229.9
80	119.5	162.6	233.6
90	118.7	162.6	237.0
100	117.7	161.6	239.2

B = C<sub>8</sub>H<sub>8</sub>O, Acetophenone  
(126)

M % B	$\varphi_{25}$
0.00	129.7
30.58	100.7
64.19	77.9
88.82	65.3
100.00	60.8

**C<sub>2</sub>H<sub>4</sub>O**

Acetaldehyde

B = C<sub>2</sub>H<sub>5</sub>O, Ethyl alcohol  
(97)

Wt. % A	$\varphi_0$
0.0	56.5
15.1	48.1
25.2	41.6
30.1	40.0
34.4	38.3
37.1	37.8
40.8	38.55
44.2	40.55

B = C<sub>2</sub>H<sub>6</sub>O—(Continued)

Wt. % A	$\varphi_0$
47.7	40.7
49.1	40.8
53.1	45.9
55.8	49.3
58.6	55.6
65.7	81.2
70.6	103.2
83.0	194.6
100.0	365.0

Wt. % A	$\varphi_{18}$
0.00	80.6
10.01	72.7
20.80	67.2
21.61	67.0
30.58	64.8
36.36	64.6
42.01	68.1
52.04	82.3
61.56	120.3
74.10	193.1
81.09	248.8
100.00	411.5

**C<sub>2</sub>H<sub>4</sub>O<sub>2</sub>**

Acetic acid

B = C<sub>3</sub>H<sub>6</sub>O, Acetone (70)

M % B	$\varphi_{25}$
0.00	89.2
9.63	96.5
19.85	108.5
30.32	124.6
40.27	143.0
50.14	164.0
59.51	186.9
69.75	215.7
79.65	247.1
90.04	286.0
100.00	326.3

M % B	$\varphi_0$ (43)	$\varphi_{18}$ (43)	$\varphi_{43}$ (43)
0	42.02	71.8	99.7
30	76.1	106.8	145.8
60	122.1	171.5	212.8
100	250.0	285.7	357.1

50 Wt. % B (102)

°C	$\varphi$
0	104.1
25	150.1
40	187.6
55	219.7
70	250.8

B = C<sub>4</sub>H<sub>8</sub>O<sub>2</sub>, Acetic anhydride (26)

Wt. % B	$\varphi_{15}$	$\varphi_{76.5}$
0.00	75.0	177.5
9.97	75.9	181.0
30.07	84.4	191.4
49.97	88.2	200.6
69.95	94.6	206.8
89.95	99.4	215.6
100.00	102.1	216.6

B = C<sub>4</sub>H<sub>8</sub>O<sub>2</sub>, Isobutyric acid  
(78)

M % B	$\varphi_{11}$
33.34	59.0

B = C<sub>4</sub>H<sub>8</sub>O<sub>2</sub>—(Continued)

M % B	$\varphi_{11}$
50	53.8
66.67	58.6
100	71.4

B = C<sub>4</sub>H<sub>8</sub>O<sub>2</sub>, Ethyl acetate  
(70)

M % B	$\varphi_{25}$
0.00	89.2
12.58	106.0
19.89	116.4
30.12	130.4
40.04	145.1
50.15	158.9
60.10	173.5
69.63	187.6
79.30	202.0
89.51	217.9
100.00	236.0

B = C<sub>4</sub>H<sub>10</sub>O, Ethyl ether (146)

Wt. % B	$\varphi_{18}$
0.00	71.7
11.55	84.2
15.15	92.4
30.96	128.1
40.37	156.0
50.64	185.9
72.91	284.0
100.00	417.9

B = C<sub>5</sub>H<sub>5</sub>N, Pyridine (43)

M % B	$\varphi_{18.4}$	$\varphi_{40}$
0	74.1	10.0
15	16.64	35.1
17.5	16.3	34.1
20	17.2	34.4
50	35.3	59.5
100	83.3	125.0

M % B	$\varphi_{70}$	$\varphi_{99}$
0	166.7	232.6
15	69.9	120.5
17.5	69.0	113.0
20	69.9	111.1
50	100.0	133.3
100	181.8	243.9

M % B  $\varphi_{20}$  (145)

M % B	$\varphi_{20}$ (145)
0.0	77.8
10.4	22.6
22.05	19.85
38.3	33.1
40.1	34.6
48.1	45.7
57.9	56.75
73.8	77.6
100.0	107.2

Wt. % B  $\varphi_{25}$  (120)

Wt. % B	$\varphi_{25}$ (120)
0.000	90.1
0.541	86.2
0.985	82.0
3.23	62.1
8.97	36.0
13.22	28.7
17.08	25.0
22.52	26.0
29.00	26.4
100.00	112.5



**B = C<sub>2</sub>H<sub>5</sub>N.—(Continued)**

23 Wt. % B (102)	
°C	φ
0	7.79
25	20.55
40	33.68
55	48.25
70	65.50

For additional data at 20, 40, and 80°C, v. (157).

**B = C<sub>6</sub>H<sub>6</sub>, Benzene (29)**

Wt. % B	φ <sub>25</sub>
0.00	85.2
16.74	112.0
34.93	136.2
48.29	150.2
77.26	167.5
81.42	167.7
89.73	169.3
97.25	168.3
100.00	167.3

g B/l	φ <sub>20</sub> (105)
0.00	79.0
2.414	79.3
5.48	79.8
9.874	81.2
27.38	83.9
49.368	86.1
136.9	98.1
880	151.8

**B = C<sub>6</sub>H<sub>7</sub>N, Aniline (140)**

Wt. % B	φ <sub>25</sub>	φ <sub>50</sub>
0.0	74.6	33.8
15.5	13.7	
24.7	8.13	
37.9	4.57	17.70
40.9	4.67	17.9
44.5	4.93	19.1
49.55	5.52	
62.3	8.48	26.2
100.0	27.62	49.8

44 Wt. % B (110, 111)	
°C	φ
25	5.49
40	12.78
55	23.87
70	38.39

Wt. % B	φ <sub>25</sub> (120)
0.00	90.1
0.704	84.8
1.72	75.2
4.22	54.6
8.49	32.6
13.85	17.7
16.71	13.0
22.17	8.14
26.58	6.18
28.33	5.63
35.77	4.59
100.00	27.47

M % B	φ <sub>18</sub> (43)	φ <sub>50</sub> (43)	φ <sub>100</sub> (43)
0	99.01	142.9	232.6
20	5.21	34.13	135.1

**B = C<sub>6</sub>H<sub>7</sub>N.—(Continued)**

M % B	φ <sub>18</sub> (43)	φ <sub>50</sub> (43)	φ <sub>100</sub> (43)
25	4.64	29.7	117.7
30	4.43	28.3	120.5
40	5.12	31.1	125.0
60	11.49	44.8	142.9
80	21.7	57.5	166.7
100	30.5	66.7	192.3

**B = C<sub>6</sub>H<sub>12</sub>O<sub>3</sub>, Paraldehyde (105)**

g B/l	φ <sub>15</sub>
0.00	76.0
3.42	75.9
17.09	75.7
47.73	74.3
85.34	72.5
238.63	67.7
426.73	65.7
707.8	67.4
883.7	71.7
984.8	74.6
990.5	76.0

g B/l	φ <sub>20</sub>
0.00	82.0
5.49	82.0
9.38	81.9
27.44	81.5
46.90	81.2
85.34	80.6
137.20	80.3
234.51	79.9
426.73	79.4
711.4	79.7
938.1	80.3
972.9	82.2
983.3	82.8
989.3	83.3
994.8	84.9

**B = C<sub>6</sub>H<sub>5</sub>O, Acetophenone (70)**

M % B	φ <sub>25</sub>
0.00	89.21
9.87	77.34
19.98	70.42
30.02	65.62
39.97	62.58
51.15	59.95
57.47	58.72
70.65	57.41
78.93	57.02
90.02	57.45
100.00	59.49

**B = C<sub>6</sub>H<sub>10</sub>O<sub>2</sub>, Ethyl benzoate (70)**

M % B	φ <sub>25</sub>
0.00	89.2
8.68	83.2
20.44	75.6
31.74	69.2
41.78	65.0
52.50	60.6
61.18	57.9
69.55	56.5
78.71	53.4
89.59	51.3
100.00	50.5

**C<sub>2</sub>H<sub>5</sub>I****Ethyl iodide****B = C<sub>4</sub>H<sub>9</sub>O<sub>2</sub>, Ethyl acetate (99)**

Wt. % B	φ <sub>25</sub>
0.00	173.3
21.80	245.1
67.43	216.5
100.0	185.5

For data at 18, 35, and 50°C, v. (157).

**B = C<sub>8</sub>H<sub>10</sub>O, Phenetole (124)**

M % B	φ <sub>0</sub>
0.00	137.9
9.56	129.0
33.98	105.4
54.71	86.1
73.85	71.2
90.89	59.7

**C<sub>2</sub>H<sub>5</sub>NO****Acetamide****B = C<sub>5</sub>H<sub>5</sub>N, Pyridine (33)**

Wt. % B	φ <sub>25</sub>
83.73	72.4
91.49	91.9
94.35	99.5
96.13	101.3

**C<sub>2</sub>H<sub>6</sub>O****Ethyl alcohol****B = C<sub>2</sub>H<sub>6</sub>S, Ethylmercaptan (27)**

Wt. % B	φ <sub>25</sub>
0.00	89.5
3.48	95.4
9.47	102.8
12.30	107.5
13.88	114.2
16.25	119.3
32.54	153.2
35.97	163.4
44.76	171.8
68.05	244.9
100.00	478.2

**B = C<sub>3</sub>H<sub>8</sub>O, Allyl alcohol (110)**

M B/l	φ <sub>20</sub>
0.25	81.9
0.5	81.2
1.0	80.9
2.0	80.0
4.0	77.4

**B = C<sub>3</sub>H<sub>6</sub>O, Acetone (105); cf. (66)**

g B/l	φ <sub>20</sub>
0.000	79.8
4.809	80.3
7.375	81.1
19.239	83.8
36.876	88.7
43.276	89.6
96.196	103.7
156.860	119.2
184.384	126.4

**B = C<sub>2</sub>H<sub>5</sub>O.—(Continued)**

Wt. % B	φ <sub>25</sub> (27)
0.00	89.7
22.46	139.5
27.77	153.6
35.11	172.3
36.83	177.3
43.38	193.7
44.50	198.9
51.57	216.5
70.34	260.7
100.00	320.0

**50 Wt. % B (105)**

°C	φ
0	129.9
25	189.0
40	237.9

v. also p. 30, A = Cu(NO<sub>3</sub>)<sub>2</sub> and p. 31, A = LiBr; A = KCNS.**B = C<sub>3</sub>H<sub>7</sub>O<sub>2</sub>, Methyl acetate (102)****50 Wt. % B**

°C	φ
0	111.2
25	163.2
40	202.1
55	241.4

**B = C<sub>3</sub>H<sub>7</sub>O, n-Propyl alcohol (55, 112)**

Wt. % B	φ <sub>25</sub>
0.00	91.7
10.0	87.3
20.0	83.5
30.0	79.8
40.0	75.8
50.0	71.3
60.0	67.8
70.0	63.7
80.0	59.9
90.0	56.3
100.0	52.5

**B = C<sub>3</sub>H<sub>7</sub>O<sub>2</sub>, Glycerol (52)**

Wt. % B	φ <sub>25</sub>	φ <sub>35</sub>	φ <sub>45</sub>
0	93.7	115.2	137.7
25	23.9	32.77	43.4
50	4.71	7.40	11.46
75	0.972	1.83	3.215
100	0.165	0.368	0.740

M B/l	φ <sub>20</sub> (110)
0.25	74.7
0.5	67.0
1.0	56.0

v. also p. 30, A = CoCl<sub>2</sub>

**B = C<sub>4</sub>H<sub>9</sub>O<sub>2</sub>, Ethyl acetate (102)****50 Wt. % B**

°C	φ
0	104.3
25	144.0
40	185.3
55	226.0



**C<sub>2</sub>H<sub>6</sub>O.—(Continued)****B = C<sub>2</sub>H<sub>10</sub>O, Ethyl ether (5)**

Wt. % B	$\varphi_{25}$
0.00	89.9
23.15	134.9
47.43	209.0
57.51	249.7
64.48	278.6
72.99	317.3
78.37	345.2
86.39	379.5
100.00	442.5
Vol. % B	$\varphi_{25}$ (6)
50	212.4
75	319.7

**B = C<sub>5</sub>H<sub>7</sub>N, Pyridine (110)**

M B/l	$\varphi_{20}$
0.25	83.0
0.5	84.1
1.0	87.2
2.0	89.9

**B = C<sub>5</sub>H<sub>10</sub>O<sub>4</sub>, Monoacetin (110)**

0.25	75.6
0.5	70.2
1.0	58.7
2.0	39.5
4.0	24.2

**B = C<sub>5</sub>H<sub>12</sub>O, Isoamyl alcohol (105)**

g B/l	$\varphi_{18.4}$
0.000	74.9
3.170	73.8
7.350	74.5
8.832	74.5
12.684	73.3
29.44	71.6
44.16	70.9
63.41	69.7
147.20	63.7
220.80	58.4
M B/l	$\varphi_{20}$ (110)
0.5	76.8
1.0	74.4
2.0	66.0
4.0	54.6

**B = C<sub>6</sub>H<sub>5</sub>ClO, Chlorophenol (136)**

21.4 Wt. % B	$\varphi_{25}$
<i>o</i> -	68.87
<i>m</i> -	68.97
<i>p</i> -	68.78

**B = C<sub>6</sub>H<sub>6</sub>, Benzene (50); cf. (46)**

Wt. % B	$\varphi_{15}$	$\varphi_{20}$	$\varphi_{25}$
0	75.7	83.9	91.7
25	90.9	98.3	108.0
50	113.5	123.5	131.8
75	139.5	152.2	160.3
100	142.1	154.1	165.0

**B = C<sub>6</sub>H<sub>6</sub>—(Continued)**

Wt. % B	$\varphi_{20}$	$\varphi_{25}$	$\varphi_{40}$
0	101.0	110.0	120.8
25	119.2	129.5	143.1
50	146.8	160.5	176.4
75	175.1	185.9	200.0
100	177.9	189.9	203.3

Wt. % B	$\varphi_{50}$	$\varphi_{60}$
0	143.3	168.9
100	228.8	255.8

Wt. % B	$\varphi_{65}$	$\varphi_{70}$
0		198.0
25	202.0	

Wt. % B	$\varphi_{70}$	$\varphi_{80}$
50		250.0
100		284.9

**Wt. % B** **$\varphi_{25}$  (27)**

0.00	88.5
8.47	98.7
17.00	104.8
28.90	113.2
45.60	128.9
50.91	137.3
67.58	153.5
69.49	154.7
76.53	164.7
80.38	170.0
88.03	176.4
98.86	176.5
100.00	171.8

**g B/l** **$\varphi_{20}$  (105)**

0.000	77.2
2.708	77.6
3.120	77.6
4.242	77.59
10.832	78.4
15.588	79.05
23.208	79.3
54.160	81.1
97.984	86.3

**50 Wt. % B (102)****°C** **$\varphi$** **0****25****40****55****70.71****121.9****161.3****201.5****B = C<sub>6</sub>H<sub>6</sub>O<sub>2</sub>, Hydroquinol (110)****M B/l** **$\varphi_{20}$** **0.25****0.5****1.0****73.2****64.7****51.9****For *o*- and *m*- isomers at 20°C, v. (152.1).****B = C<sub>6</sub>H<sub>10</sub>O<sub>3</sub>, Ethyl acetoacetate (35)****Wt. % B** **$\varphi_{25}$** **0.00****8.05****36.28****46.71****64.02****100.00****93.7****97.7****103.9****102.1****96.4****66.3****B = C<sub>6</sub>H<sub>12</sub>, Cyclohexane; for data at 20°C, v. (152.2).****B = C<sub>6</sub>H<sub>11</sub>O<sub>2</sub>, Paraldehyde (105)****g B/l** **$\varphi_{20}$** **0.0****5.64****8.33****22.56****41.68****112.8****208.4****994.8****79.8****79.9****80.3****81.3****81.9****85.1****89.2****84.9****B = C<sub>6</sub>H<sub>14</sub>O<sub>2</sub>, Acetal (110)****M B/l** **$\varphi_{20}$** **0.25****0.5****1.0****85.4****87.9****95.4****B = C<sub>7</sub>H<sub>6</sub>O, Benzaldehyde (27)****Wt. % B** **$\varphi_{25}$** **0.00****11.65****20.67****23.60****32.47****53.96****79.32****90.63****100.00****89.9****91.6****95.2****95.2****96.1****86.4****76.5****73.4****69.2****B = C<sub>7</sub>H<sub>6</sub>O<sub>2</sub>, Salicylaldehyde; for data at 20°C, v. (152.1).****B = C<sub>7</sub>H<sub>6</sub>O, Anisole (5)****Wt. % B** **$\varphi_{25}$** **0.00****15.21****29.62****43.00****55.67****67.68****79.05****89.98****100.00****89.9****95.7****101.1****105.6****108.9****110.6****110.5****108.2****99.2****B = C<sub>7</sub>H<sub>6</sub>O<sub>2</sub>, *o*-Hydroxybenzyl alcohol (110)****M B/l** **$\varphi_{20}$** **0.25****0.5****1.0****75.5****68.3****58.4****B = C<sub>7</sub>H<sub>6</sub>O<sub>2</sub>, Guaiacol; for data at 20°C, v. (152.1).****B = C<sub>9</sub>H<sub>10</sub>O, Phenetole (5)****Wt. % B** **$\varphi_{25}$** **0.00****14.97****28.89****42.32****54.97****67.05****78.50****90.25****100.00****89.9****93.7****96.6****99.0****100.3****100.9****100.0****96.6****88.1****B = C<sub>8</sub>H<sub>10</sub>O<sub>2</sub>, *o*-Dimethoxybenzene; for data at 20°C, v. (152.1).****B = C<sub>8</sub>H<sub>14</sub>O<sub>2</sub>, Ethyl ethyl-acetoacetate (35)****Wt. % B** **$\varphi_{25}$** **0.00****5.44****23.80****41.24****71.31****87.87****100.00****92.7****94.0****96.3****94.5****83.1****72.2****59.6****B = C<sub>8</sub>H<sub>7</sub>N, Quinoline (74)****0.00****13.30****23.50****39.09****50.23****62.65****68.98****75.69****85.57****92.09****100.00****92.7****91.6****78.56****71.4****60.95****53.28****49.6****41.30****38.70****34.29****29.75****B = C<sub>10</sub>H<sub>7</sub>Br,  $\alpha$ -Bromonaphthalene (110)****M B/l** **$\varphi_{20}$** **0.25****0.5****1.0****78.6****75.7****71.5****B = C<sub>10</sub>H<sub>12</sub>, 1, 2, 3, 4-Tetrahydronaphthalene (59)****Wt. % B** **$\varphi_{25}$** **0.0****24.6****48.3****75.8****92.3****100.0****92.0****85.4****78.4****67.0****57.3****49.9****v. also (152.2)****B = C<sub>10</sub>H<sub>12</sub>O, Anethole and *ar*-Tetrahydro- $\beta$ -naphthol; for data at 20°C, v. (152.2).****B = C<sub>10</sub>H<sub>16</sub>O, Camphor (110)****M B/l** **$\varphi_{20}$** **0.25****0.5**



**B = C<sub>14</sub>H<sub>10</sub>O<sub>2</sub>, Benzil (143)**

g B/kg A	$\varphi_{15}$
0.00	75.9
6.82	75.6
11.36	75.3
20.39	74.9
g B/kg A	$\varphi_{40}$
0.00	119.3
12.06	118.0
25.74	116.7
38.24	115.5
47.17	114.4

**B = C<sub>18</sub>H<sub>36</sub>O<sub>2</sub>, Stearic acid (110)**

M B/l	$\varphi_{20}$
0.25	77.2
0.5	71.4
1.0	61.5

**B = C<sub>22</sub>H<sub>20</sub>O<sub>13</sub>, Carminic acid (154)**

0.03125	77.4
0.0625	73.4
0.125	66.1

**B = C<sub>34</sub>H<sub>47</sub>NO<sub>11</sub>, Aconitine (110)**

0.02	80.4
0.04	77.7

**C<sub>2</sub>H<sub>7</sub>N****Dimethylamine****B = C<sub>2</sub>H<sub>5</sub>ClN, Dimethylamine hydrochloride (40)**

M B/l	$\varphi_{-33.5}$
0.2843	189.3
0.3585	181.9
0.7857	135.9
0.8535	111.8

**C<sub>2</sub>H<sub>7</sub>N****Ethylamine****B = C<sub>2</sub>H<sub>5</sub>ClN, Ethylamine hydrochloride (40)**

M A/l	$\varphi_{-33.5}$
0.09458	162.2
0.1898	150.7
0.3817	131.3
0.7518	101.4
1.489	53.7

**C<sub>3</sub>H<sub>3</sub>N<sub>3</sub>O<sub>3</sub>****Cyanuric acid****B = C<sub>5</sub>H<sub>5</sub>N, Pyridine (33)**

Wt. % B	$\varphi_{25}$
96.8	96.3

**C<sub>3</sub>H<sub>5</sub>NS****Ethyl thiocyanate****B = C<sub>5</sub>H<sub>11</sub>N, Piperidine (91)**

M % B	$\varphi_{50}$
0	208.3
5	176.4
25	59.5
45	4.42
50	0.924
55	2.06
75	22.8
95	92.9
100	118.3

**C<sub>3</sub>H<sub>6</sub>O****Acetone****B = C<sub>3</sub>H<sub>8</sub>O, Isopropyl alcohol (158)****B = C<sub>4</sub>H<sub>10</sub>O, Ethyl ether (43)**

M % B	$\varphi_0$	$\varphi_{14}$	$\varphi_{32}$
0	261.1	307.7	387.6
30	287.4	341.3	408.2
70	325.1	380.2	438.6
100	333.3	400.0	465.1

**B = C<sub>6</sub>H<sub>5</sub>Br, Bromobenzene****M % B** **$\varphi_0$  (126)**

0.00	250.0
6.25	225.2
17.50	186.6
28.15	158.2
50.15	115.9
73.54	85.4
84.32	78.3
100.00	66.7

**B = C<sub>6</sub>H<sub>5</sub>Cl, Chlorobenzene****M % B** **$\varphi_0$  (126)**

0.00	250.0
4.03	238.7
15.26	208.8
39.70	166.1
50.88	143.5
84.70	104.9
100.00	96.7

**B = C<sub>6</sub>H<sub>5</sub>ClO, *o*-Chlorophenol (17)**

Wt. % B	$\varphi_0$	$\varphi_{10}$	$\varphi_{20}$
0.00	253.0	277.8	309.2
18.49	171.8	189.8	210.5
32.38	127.1	144.5	163.7
49.95	71.5	86.1	100.8
60.49	46.8	59.45	72.7
71.01	27.86	37.38	48.76
83.22	14.82	22.37	31.55
91.73	10.64	17.24	25.58
100.00	9.27	15.65	23.75

Wt. % B	$\varphi_{30}$	$\varphi_{40}$	$\varphi_{50}$
0.00	339.0	370.4	403
18.49	238.7	261.8	284
32.38	175.7	196.9	215
49.95	112.0	128.7	145.6
60.49	83.4	98.1	112.0
71.01	59.4	73.1	86.7
83.22	41.7	53.0	65.5
91.73	35.1	46.2	57.6
100.00	32.5	43.1	53.5

Wt. % B	$\varphi_{60}$	$\varphi_{70}$
59.37	137.2	156.0
68.23	108.9	126.4
76.99	90.3	105.0
84.64	77.6	92.0
91.08	70.3	84.2
100.00	66.1	79.0

**B = C<sub>6</sub>H<sub>5</sub>NO<sub>2</sub>, Nitrobenzene****Vol. % B** **$\varphi_{25}$  (47)**

0	317.5
25	203.9

**B = C<sub>6</sub>H<sub>5</sub>NO<sub>2</sub>,—(Continued)****Vol. % B** **$\varphi_{25}$  (47)**

50	139.1
75	92.1
100	55.2

**g B/l** **$\varphi_{20}$  (105)**

937.7	74.1
1037.7	66.1
1080.7	61.0
1150.8	54.0
1177.1	52.4
1183.2	51.8
1192.2	51.2
1197.1	50.5
1204.8	49.64

**B = C<sub>6</sub>H<sub>6</sub>, Benzene (13)****Wt. % B** **$\varphi_{10}$**  **$\varphi_{20}$**  **$\varphi_{30}$** 

0.0	278.8	309.6	342.3
21.24	251.2	280.5	311.1
49.34	213.2	240.9	268.2
72.14	173.9	203.6	230.2
100.00	131.9	154.7	178.7

**Vol. % B** **$\varphi_{25}$  (47)**

0	317.4
25	285.1
50	250.2
75	212.1
100	173.7

**g B/l** **$\varphi_{20}$  (105)**

699.8	185.8
789.3	172.0
840.5	162.1
858.8	159.1
869.7	157.4
873.5	156.4
880.0	155.6

**B = C<sub>6</sub>H<sub>5</sub>O, Phenol (17)****Wt. % B** **$\varphi_{9.95}$**  **$\varphi_{20.05}$** 

0.00	277.8	309.6
14.19	205.8	233.1
26.72	157.5	178.6
38.06	115.2	132.4
49.43	79.6	94.8
57.79	59.2	72.5
65.22	42.4	54.0
73.74	27.25	36.4
78.94	20.2	27.9
85.39	13.37	20.1
92.85	8.38	13.7
100.00	4.98	9.06

**Wt. % B** **$\varphi_{29.3}$**  **$\varphi_{40.1}$**  **$\varphi_{49.8}$** 

0.00	339.0	370.4	403.2
9.57	277.8	304.9	334.4
19.53	226.8	250.6	277.8
27.70	191.9	212.8	237.0
37.42	149.3	169.5	188.7
44.67	123.8	140.6	159.2
53.79	94.5	110.6	125.9
60.24	75.8	90.8	105.3
67.19	60.3	73.4	87.0
74.25	45.9	57.4	70.2
80.76	36.4	44.6	56.0
87.98	25.5	34.8	44.5
92.81	20.4	28.9	38.2
100.00	14.1	21.1	30.5

**B = C<sub>6</sub>H<sub>6</sub>O<sub>2</sub>, *o*- and *m*-Dihydroxybenzene; for data at 20°C, v. (152.1).****B = C<sub>6</sub>H<sub>7</sub>N, Aniline (43)****M % B** **$\varphi_{18}$**  **$\varphi_{41}$** 

0	333.3	400.0
40	115.9	170.1
70	53.3	90.1
100	29.6	48.2

**50 Wt. % B (102)****°C** **$\varphi$** 

0	70.3
25	113.4
40	146.7
55	176.5
70	205.2

**B = C<sub>6</sub>H<sub>12</sub>, Cyclohexane; for data at 20°C, v. (152.2).****B = C<sub>6</sub>H<sub>14</sub>, Hexane (105)****g B/l** **$\varphi_{20}$** 

572.2	295.2
623.8	289.0
684.3	280.4
685.1	276.5
687.2	276.0

**B = C<sub>7</sub>H<sub>6</sub>O<sub>2</sub>, Salicylaldehyde; for data at 20°C, v. (152.1).****B = C<sub>7</sub>H<sub>8</sub>O<sub>2</sub>, Guaiacol; for data at 20°C, v. (152.1).****B = C<sub>7</sub>H<sub>14</sub>O<sub>2</sub>, Amyl acetate (31)****Wt. % B** **$\varphi_{25}$** 

81.60	160.7
91.41	145.4
100.00	126.7

**B = C<sub>8</sub>H<sub>10</sub>O<sub>2</sub>, *o*-Dimethoxybenzene; for data at 20°C, v. (152.1).****B = C<sub>10</sub>H<sub>8</sub>O,  $\beta$ -Naphthol; for data at 20°C, v. (152.2).****B = C<sub>10</sub>H<sub>12</sub>, Tetrahydronaphthalene; for data at 20°C, v. (152.2).****B = C<sub>10</sub>H<sub>12</sub>O, *ar*-Tetrahydro- $\beta$ -naphthol; for data at 20°C, v. (152.2).****B = C<sub>12</sub>H<sub>10</sub>O, Phenyl ether (126)****M % B** **$\varphi_{25}$** 

0.0	320.5
10.60	227.8
26.94	140.1
51.57	74.7
100.00	27.3

**C<sub>3</sub>H<sub>6</sub>O<sub>2</sub>****Propionic acid****B = C<sub>5</sub>H<sub>5</sub>N, Pyridine; for data at 20, 40, and 80°C, v. (157).**



**C<sub>3</sub>H<sub>6</sub>O<sub>2</sub>**

Methyl acetate

B = C<sub>4</sub>H<sub>8</sub>O<sub>2</sub>, Ethyl acetate (78)

M % B	$\varphi_{11}$
0	162.2
25	158.6
50	155.8
66.58	153.4

**C<sub>3</sub>H<sub>7</sub>NO**

Methylacetamide

B = C<sub>4</sub>H<sub>8</sub>N, Pyridine (33)

Wt. % B	$\varphi_{25}$
83.56	92.4
88.80	97.9
93.41	103.4

**C<sub>3</sub>H<sub>7</sub>NO**

Propionamide

B = C<sub>4</sub>H<sub>8</sub>N, Pyridine (33)

Wt. % B	$\varphi_{25}$
76.25	61.9
86.34	82.9
92.08	95.5

**C<sub>3</sub>H<sub>7</sub>NO<sub>2</sub>**

Urethane

B = C<sub>4</sub>H<sub>8</sub>N, Pyridine (33)

Wt. % B	$\varphi_{25}$
85.04	83.2
90.91	93.5

**C<sub>3</sub>H<sub>8</sub>O**

n-Propyl alcohol

B = C<sub>4</sub>H<sub>8</sub>O<sub>2</sub>, Glycerol (110)

M B/l	$\varphi_{20}$
1.0	29.6

B = C<sub>4</sub>H<sub>10</sub>O, Ethyl ether (5)

Wt. % B	$\varphi_{25}$
0.0	50.7
11.93	71.2
22.99	97.7
34.92	132.8
47.16	178.0
59.89	234.0
72.97	298.2
86.22	368.1
100.0	442.5

**C<sub>3</sub>H<sub>8</sub>O**

n-Propyl alcohol

B = C<sub>6</sub>H<sub>6</sub>, Benzene (29)

Wt. % B	$\varphi_{25}$
0.0	51.0
4.93	85.7
10.01	142.3
29.78	166.9
66.90	169.0
100.0	167.3

B = C<sub>6</sub>H<sub>7</sub>N, Aniline (78)

M % B	$\varphi_{12}$	$\varphi_{64}$
0	38.3	166.8
20	36.8	160.5
65	26.4	128.8
100	17.2	99.4

**C<sub>3</sub>H<sub>8</sub>O<sub>3</sub>**

Glycerol

B = C<sub>8</sub>H<sub>12</sub>O, Isoamyl alcohol (111)

M A/l	$\varphi_{20}$
1.0	14.47

**C<sub>4</sub>H<sub>5</sub>Cl<sub>3</sub>O<sub>2</sub>**

Ethyl trichloroacetate

B = C<sub>4</sub>H<sub>5</sub>O<sub>2</sub>, Ethyl acetate (78)

M % A	$\varphi_{11}$
22.82	110.9
50	80.4
63.47	72.0
100.00	47.6

**C<sub>4</sub>H<sub>5</sub>NS**

Allyl thiocyanate

B = C<sub>5</sub>H<sub>5</sub>N, Pyridine (92)

M % B	$\varphi_{25}$
0	148.6
50	138.5
100	117.1

B = C<sub>5</sub>H<sub>11</sub>N, Piperidine (92)

M % B	$\varphi_{25}$	$\varphi_{50}$	$\varphi_{80}$
0	148.6	184.8	234.2
10	85.5		
25	24.08		
40	2.68		
40.91	2.64		22.8
45	0.846	4.21	13.27
48	0.402	2.88	12.75
50	0.283	1.82	10.71
52	0.384	2.37	12.78
55	0.581	3.22	13.06
60	1.467		
75	9.57		
90	38.8		134.1
100	73.4	118.3	135.5

B = C<sub>6</sub>H<sub>7</sub>N, Aniline (86)

M % B	$\varphi_{100}$	$\varphi_{125}$
0	316.5	380
10	221.2	274.0
20	127.4	158.7
30	54.3	69.3
40	22.7	35.8
48	12.07	27.6
50	11.03	26.6
52	12.71	29.0
60	24.9	43.6
70	45.7	73.9
80	74.5	110.0
90	109.6	160.5
100	144.7	203.3

B = C<sub>7</sub>H<sub>8</sub>, Toluene (86)

M % B	$\varphi_{25}$	$\varphi_{100}$
25	297	325
50	315.5	351
75	333	357

B = C<sub>7</sub>H<sub>8</sub>N, Methylaniline (91)

M % B	$\varphi_{25}$	$\varphi_{50}$
0	148.6	184.8
10	85.3	115.5
25	39.2	47.06

B = C<sub>7</sub>H<sub>9</sub>N.—(Continued)

M % B	$\varphi_{25}$	$\varphi_{80}$
40	9.82	19.76
48	3.24	10.29
50	2.85	8.64
52	3.17	
55	3.98	12.00
60	6.22	17.5
75	18.6	40.3
90	31.9	62.5
100	50.0	67.8

**C<sub>4</sub>H<sub>6</sub>O<sub>3</sub>**

Acetic anhydride

B = C<sub>6</sub>H<sub>12</sub>O<sub>3</sub>, Paraldehyde (26)

Wt. % B	$\varphi_{10}$	$\varphi_{76.5}$
0.00	94.5	216.6
10.00	89.2	212.3
29.96	82.1	211.0
50.00	75.2	206.7
69.99	69.3	205.1
90.02	66.4	207.1
100.00	65.5	209.2

**C<sub>4</sub>H<sub>8</sub>O<sub>2</sub>**

Butyric acid

B = C<sub>5</sub>H<sub>8</sub>N, Pyridine; for data at 18, 30 and 40°C, v. (157).**C<sub>4</sub>H<sub>8</sub>O<sub>2</sub>**

-Ethyl acetate

B = C<sub>5</sub>H<sub>8</sub>N, Pyridine (102)

50 Wt. % B

°C	$\varphi$
0	122.0
25	170.0
40	194.0
55	219.2

B = C<sub>6</sub>H<sub>5</sub>NO<sub>2</sub>, Nitrobenzene (99)

Wt. % B	$\varphi_{25}$
0.00	229.9
22.90	171.8
56.10	112.5
75.53	83.1
100.00	54.5

50 Wt. % B (102)

°C	$\varphi$
0	84.02
25	122.6
40	153.8
55	179.3
70	202.9

B = C<sub>6</sub>H<sub>6</sub>, Benzene (27); cf. (99)

Wt. % B	$\varphi_{25}$
0.00	238.5
24.05	224.9
50.90	209.1
51.70	208.2
56.07	207.0
64.16	200.4
66.90	200.4
72.96	193.0
100.00	171.8

B = C<sub>6</sub>H<sub>6</sub>.—(Continued)

50 Wt. % B (102)

°C	$\varphi$
0	149.3
25	206.6
40	251.2
55	289.5

B = C<sub>6</sub>H<sub>7</sub>N, Aniline (153)

M % B	$\varphi_{11}$
0.0	170.0
15.2	122.2
22.34	104.0
42.8	63.6
50.77	53.9
67.2	34.8
74.9	25.8
77.6	23.5
84.2	19.0
88.9	14.2
93.9	12.5
100.0	10.03

B = C<sub>7</sub>H<sub>8</sub>, Toluene (99)

Wt. % B	$\varphi_{25}$
0.0	216.5
15.71	214.6
45.30	207.9
71.26	196.5
100.00	185.5

B = C<sub>7</sub>H<sub>14</sub>O<sub>2</sub>, Iso (?) amyl acetate (78)

M % B	$\varphi_{11}$
20.6	111.4
50	105.0
100	63.3

B = C<sub>8</sub>H<sub>14</sub>O<sub>4</sub>, Diethyl succinate (78)

M % B	$\varphi_{12}$	$\varphi_{64}$
0	151.7	304.8
25	101.4	221.5
50	67.8	176.7
62.5	52.9	157.4
75	45.8	146.3
90	33.4	130.1
100	29.9	119.9

B = C<sub>9</sub>H<sub>10</sub>O<sub>2</sub>, Ethyl benzoate (73)

M % B	$\varphi_{25}$
0.00	235.9
10.08	192.7
20.03	161.9
30.11	138.0
40.02	118.0
49.56	101.5
60.27	86.4
68.69	77.4
79.12	66.0
87.84	58.7
100.00	49.6

M % B	$\varphi_{12}$ (78)	$\varphi_{64}$ (78)
0	151.7	302.9
25	111.2	240.3
40	62.7	
75	55.4	158.7
100	38.7	133.4



**B = C<sub>10</sub>H<sub>22</sub>O, Isoamyl ether (78)**

Wt. % B	$\varphi_{11}$
16.83	133.4
43.50	113.2
74.95	88.2
100.00	71.4

**B = C<sub>14</sub>H<sub>12</sub>O<sub>2</sub>, Benzyl benzoate (73)**

M % B	$\varphi_{25}$
0.0	235.9
10.2	156.1
20.10	109.7
30.27	78.4
41.37	55.9
50.00	43.5
59.99	32.8
69.98	25.77
76.53	21.23
85.74	16.84
92.16	14.28
100.00	11.74

### C<sub>4</sub>H<sub>9</sub>NO<sub>2</sub>

Methylurethane

**B = C<sub>10</sub>H<sub>20</sub>O, Menthol (132)**

Wt. % B	$\varphi_{55.6}$	$\varphi_{74.6}$
0.00	43.9	72.9
33.38	38.0	68.2
56.80	32.8	55.9
74.28	25.8	59.5
84.39	25.9	53.4
92.46	20.1	42.4
100.00	15.9	40.5

Wt. % B	$\varphi_{82.2}$	$\varphi_{99}$
0.00	80.8	118.1
33.38	81.0	
56.80	101.4	101.4
74.28	74.6	116.9
84.39	66.9	95.1
92.46	54.5	88.7
100.00	54.0	96.1

### C<sub>4</sub>H<sub>10</sub>O

Butyl alcohol

**B = C<sub>10</sub>H<sub>18</sub>, 1, 2, 3, 4-Tetrahydronaphthalene (59)**

Wt. % B	$\varphi_{25}$
0.00	40.6
28.34	47.6
57.13	53.8
71.30	56.0
84.90	56.1
100.00	49.9

**B = C<sub>10</sub>H<sub>18</sub>, Decahydronaphthalene (59)**

0.00	40.6
32.38	44.4
49.43	46.5
67.12	47.9
82.59	47.1
89.80	46.1
100.00	41.4

### C<sub>4</sub>H<sub>10</sub>O

Ethyl ether

**B = C<sub>6</sub>H<sub>6</sub>, Benzene (99)**

Wt. % B	$\varphi_{25}$
0.00	434.8
28.58	354.6
56.92	276.2
75.69	228.3
100.00	166.9

(50)

Wt. % B	$\varphi_{15}$	$\varphi_{20}$	$\varphi_{25}$
0	404.9	425.5	448.4
25	320.5	333.3	347.2
50	253.2	262.5	273.8
75	186.2	207.5	219.2
100	142.1	154.1	165.0

Wt. % B	$\varphi_{30}$	$\varphi_{35}$
0	471.7	
25	359.7	
50	289.0	310.6
75	232.6	245.1
100	177.9	189.8

(13)

Wt. % B	$\varphi_{10}$	$\varphi_{20}$	$\varphi_{30}$
0.00	386.0	426.5	469.4
35.15	287.2	319.8	353.2
55.58	235.3	264.3	295.5
79.52	176.7	203.4	230.6
100.00	131.9	154.7	178.7

**B = C<sub>6</sub>H<sub>6</sub>O<sub>2</sub>, *o*- and *m*-Dihydroxybenzene; for data at 20°C, *v.* (152.1).**

**B = C<sub>6</sub>H<sub>14</sub>O<sub>2</sub>, Acetal (124, 125)**

M % B	$\varphi_0$	$\varphi_{25}$
0.00	347	446
9.97	266	
21.62		263
28.18	158	
45.12		149.5
46.04	89.8	
69.73		73.6
70.90	37.9	
87.32	19.2	
100	10.0	27.5

**B = C<sub>7</sub>H<sub>6</sub>O<sub>2</sub>, Salicylaldehyde; for data at 20°C, *v.* (152.1).**

**B = C<sub>7</sub>H<sub>8</sub>, Toluene (50)**

Wt. % B	$\varphi_{15}$	$\varphi_{20}$	$\varphi_{25}$
0	404.9	423.7	448.4
25	319.5	333.0	344.8
50	253.8	263.9	277.8
75	206.6	213.7	224.7
100	159.5	170.6	180.8

Wt. % B	$\varphi_{30}$	$\varphi_{35}$
0	471.7	
25	355.9	367.6
50	289.9	302.1
75	238.7	247.5
100	192.3	212.8

**B = C<sub>7</sub>H<sub>8</sub>O, Benzyl alcohol (6)**

$\varphi_{25} = 101.3$  with 50 Vol. % B

**B = C<sub>7</sub>H<sub>8</sub>O<sub>2</sub>, Guaiacol; for data at 20°C, *v.* (152.1).**

**B = C<sub>8</sub>H<sub>10</sub>O, Phenetole (73)**

M % B	$\varphi_{25}$
0.0	447.8
9.96	374.0
16.97	327.1
25.18	286.2
31.18	258.7
39.52	227.0
44.21	207.9
48.94	194.0
54.99	175.0
64.84	150.0
69.74	139.8
74.77	127.3
81.45	115.3
90.25	100.1
92.55	97.4
100.00	86.5

**B = C<sub>8</sub>H<sub>10</sub>O<sub>2</sub>, *o*-Dimethoxybenzene; for data at 20°C, *v.* (152.1).**

**B = C<sub>12</sub>H<sub>10</sub>O, Phenyl ether (73)**

M % B	$\varphi_{25}$
0.0	447.8
9.8	322.0
21.74	219.7
29.12	174.4
39.24	131.4
48.98	100.7
57.55	79.5
67.03	61.3
78.07	46.4
86.82	36.5
92.96	31.7
100.00	25.9

### C<sub>4</sub>H<sub>11</sub>N

Diethylamine

**B = C<sub>7</sub>H<sub>7</sub>NS, Phenyl thiocyanate (86)**

M % B	$\varphi_{25}$	$\varphi_{35}$
0	289.0	358.4
10	151.3	178.6
25	17.14	25.9
33.3	2.562	4.574
40	0.1898	0.4404
45	0.0385	0.1049
48	0.01129	0.0450
50	0.00270	0.0204
52	0.0246	0.09575
55	0.0576	0.202
60	0.5057	1.267
75	8.970	13.4
90	38.0	46.3
100	71.6	83.4

M % B	$\varphi_{50}$
45	0.710
48	0.303
50	0.189
52	0.522
55	0.765
60	3.644
75	22.54
90	60.39
100	102.25

### C<sub>5</sub>H<sub>5</sub>N

Pyridine

**B = C<sub>6</sub>H<sub>5</sub>ClO, *o*-Chlorophenol (17)**

Wt. % B	$\varphi_0$	$\varphi_{10}$	$\varphi_{20}$
0.00	75.6	90.2	106.3
11.17	60.2	72.4	86.4
21.62	46.0	56.7	68.5
31.57	33.5	42.5	52.5
42.31	22.5	29.8	38.2
51.48	14.08	19.7	27.1
60.15	8.35	13.0	18.94
67.47	5.47	9.29	14.66
72.51	4.38	7.84	12.82
76.93	3.80	7.22	12.15
81.06	3.71	7.13	12.26
85.17	3.99	7.54	13.19
92.51	5.52	9.96	16.75
100.00	9.27	15.65	23.75

Wt. % B	$\varphi_{30}$	$\varphi_{40}$	$\varphi_{60}$
0.00	121.8	140.1	173.0
11.17	100.6	115.9	145.8
21.62	80.1	93.2	120.5
31.57	63.0	74.0	98.5
42.31	46.5	56.4	77.5
51.48	33.8	43.3	62.8
60.15	25.5	33.56	51.7
67.47	21.2	28.33	45.8
72.51	19.2	26.46	43.8
76.93	18.5	26.04	43.7
81.06	18.66	26.46	44.8
85.17	19.84	28.17	47.4
92.51	24.33	34.01	54.5
100.00	32.47	43.10	66.1

Wt. % B	$\varphi_{80}$	$\varphi_{110}$
0.00	205.3	259.7
11.17	176.1	223.2
21.62	148.8	193.8
31.57	124.7	166.7
42.31	101.4	142.0
51.48	84.4	125.3
60.15	73.0	113.0
67.47	67.25	105.8
72.51	65.4	103.7
76.93	65.3	104.0
81.06	66.9	106.2
85.17	70.2	110.4
92.51	79.6	119.5
100.00	93.5	131.6

**B = C<sub>6</sub>H<sub>5</sub>NO<sub>2</sub>, *o*-Nitrophenol (17)**

Wt. % B	$\varphi_{30}$	$\varphi_{40}$
0.00	121.8	140.1
11.32	106.0	122.7
20.74	92.5	107.5
27.58	82.6	97.1
39.62	66.7	80.3
52.25	53.2	66.2
60.24	46.5	58.4
68.32	40.8	52.3
76.79	36.3	46.6
86.96	31.8	41.5
91.25	30.0	39.6
100.00	27.4	36.3



**C<sub>3</sub>H<sub>3</sub>N.—(Continued)****B = C<sub>6</sub>H<sub>5</sub>NO<sub>3</sub>—(Continued)**

Wt. % B	$\varphi_{60.1}$	$\varphi_{80}$
0.00	173.0	205.3
11.32	154.6	185.5
20.74	139.1	169.5
27.58	127.2	157.5
39.62	108.1	138.1
52.25	91.6	119.6
60.24	82.5	109.8
68.32	75.5	100.8
76.79	68.5	92.6
86.96	61.7	83.7
91.25	59.2	80.6
100.00	54.8	74.2

**B = C<sub>6</sub>H<sub>5</sub>O, Phenol (17)**

Wt. % B	$\varphi_{10}$
0.00	90.2
17.26	62.7
26.01	48.8
35.14	37.4
45.48	26.6
51.89	19.8
58.46	14.71
66.99	10.12
76.81	7.06
82.86	6.08
91.89	5.32
100.00	4.96

Wt. % B	$\varphi_{20}$	$\varphi_{30}$	$\varphi_{40}$
0.00	106.3	121.8	140.1
8.30	90.2	106.4	120.8
16.12	75.7	90.4	103.6
24.36	62.6	74.7	86.8
32.58	49.8	61.2	72.0
38.94	41.5	50.94	61.3
47.13	31.1	39.77	49.0
54.96	22.9	30.82	39.1
63.81	16.83	23.31	30.8
70.49	13.37	19.34	26.3
77.94	11.02	16.56	23.2
85.17	9.96	15.10	21.8
92.45	9.33	14.46	21.3
100.00	9.06	14.10	21.1

Wt. % B	$\varphi_{60}$	$\varphi_{80}$	$\varphi_{110}$
0.00	173.0	205.3	259.7
8.30	152.4	183.8	233.6
16.12	132.8	162.9	210.5
24.36	113.8	140.2	186.9
32.58	96.9	122.7	165.0
38.94	83.5	107.1	149.5
47.13	69.6	92.8	133.2
54.96	57.9	79.2	118.9
63.81	48.4	69.2	107.0
70.49	43.5	63.3	101.2
77.94	40.0	60.4	98.7
85.17	40.0	59.9	98.8
92.45	38.6	60.6	101.5
100.00	39.7	63.3	106.3

**B = C<sub>6</sub>H<sub>7</sub>N, Aniline (43)**

M % B	$\varphi_0$	$\varphi_{10}$
0	71.4	87.0
50	27.7	48.8
100	11.6	29.1

**B = C<sub>6</sub>H<sub>7</sub>N.—(Continued)**

M % B	$\varphi_{58.6}$	$\varphi_{100}$
0	170.1	250.0
50	105.2	200.0
100	66.7	160.0

Vol. % B	$\varphi_{25} (121)$
0	112.2
50	53.8
80	36.6
100	27.0

**B = C<sub>6</sub>H<sub>10</sub>O<sub>3</sub>, Ethyl acetoacetate (35)**

Wt. % B	$\varphi_{25}$
0.00	113.6
17.11	107.6
32.09	100.8
51.00	91.74
71.07	81.10
100.00	66.31

**B = C<sub>7</sub>H<sub>5</sub>O<sub>2</sub>, Benzoic acid (8)**

Wt. % B	$\varphi_{110}$	$\varphi_{125}$
0	272.8	
40	114.2	141.0
50	95.1	116.9
56	78.1	99.0
60	74.7	95.5
62	74.6	95.9
63	69.6	90.4
66.66	64.4	86.7
69	66.4	86.0
72	67.2	89.8
78	67.4	87.6
82	66.8	87.0
86	66.5	85.2
92		87.0
100		94.9

**B = C<sub>7</sub>H<sub>7</sub>NO, Benzamide (34)**

Wt. % B	$\varphi_{25}$
5.16	94.8
12.46	75.1

**B = C<sub>7</sub>H<sub>7</sub>NO, Formanilide (33)**

	$\varphi_{10}$	$\varphi_{20}$
10.32	91.8	
19.14	74.9	

**B = C<sub>7</sub>H<sub>5</sub>O, o-Cresol (17)**

Wt. % B	$\varphi_0$	$\varphi_{10}$	$\varphi_{20}$
0.00	75.6	90.2	106.3
12.05	59.9	71.6	85.0
24.55	42.8	52.6	64.3
33.60	31.7	40.2	50.4
45.83	18.81	25.6	33.76
55.91	10.68	15.8	22.45
66.83	5.48	9.36	14.61
77.73	3.17	6.20	10.80
85.72	2.65	5.52	9.96
91.85	2.55	5.44	9.99
100.00	2.52	5.59	10.46

Wt. % B	$\varphi_{20}$	$\varphi_{40}$	$\varphi_{60}$
0.00	121.8	140.1	173.0
12.05	97.8	112.9	142.2
24.55	74.1	87.1	112.5
33.60	58.0	69.6	93.6
45.83	39.1	48.9	70.2
55.91	27.6	36.4	56.0

**B = C<sub>7</sub>H<sub>5</sub>O.—(Continued)**

Wt. % B	$\varphi_{30}$	$\varphi_{40}$	$\varphi_{60}$
66.83	20.26	28.0	45.8
77.73	16.05	23.3	40.6
85.72	15.23	22.6	40.6
91.85	15.50	23.1	41.7
100.00	16.33	24.4	44.6

Wt. % B	$\varphi_{80}$	$\varphi_{110}$
0.00	205.3	259.7
12.05	170.4	221.7
24.55	138.9	184.2
33.60	117.4	162.6
45.83	94.3	136.6
55.91	79.8	119.9
66.83	68.2	105.8
77.73	63.05	102.0
85.72	63.6	103.2
91.85	65.45	106.2
100.00	69.9	111.5

**B = C<sub>7</sub>H<sub>5</sub>O, m-Cresol (17)**

Wt. % B	$\varphi_0$	$\varphi_{10}$	$\varphi_{20}$
0.00	75.6	90.2	100.6
14.09	55.8	68.2	81.4
27.45	37.8	47.5	56.5
41.40	23.36	30.8	39.4
46.92	18.05	24.9	32.4
55.33	11.39	16.85	23.5
61.80	7.79	12.44	17.91
70.62	4.53	7.78	12.26
75.90	3.23	6.01	10.12
85.17	2.00	4.22	7.65
91.41	1.56	3.50	6.75
100.00	1.19	2.89	5.92

Wt. % B	$\varphi_{30}$	$\varphi_{40}$	$\varphi_{60}$
0.00	121.8	140.1	173.0
14.09	91.1	107.4	136.8
27.45	68.4	80.6	105.4
41.40	47.1	57.7	78.9
46.92	39.8	49.45	70.5
55.33	29.85	38.4	57.0
61.80	23.95	31.75	49.5
70.62	17.95	25.03	41.2
75.90	15.34	21.9	38.2
85.17	12.68	19.0	35.1
91.41	11.57	17.9	33.8
100.00	10.56	16.9	33.4

Wt. % B	$\varphi_{80}$	$\varphi_{110}$
0.00	205.3	259.7
14.47	166.9	218.8
26.75	136.8	185.5
38.43	111.0	154.8
50.72	87.2	129.0
61.52	71.1	109.9
70.94	61.4	99.0
82.33	55.0	93.1
90.88	54.1	95.1
100.00	55.2	97.8

**B = C<sub>7</sub>H<sub>5</sub>O, p-Cresol (17)**

Wt. % B	$\varphi_0$	$\varphi_{10}$	$\varphi_{20}$
0.00	75.6	90.2	106.3
21.03	45.9	54.4	68.9
29.61	35.8	44.4	55.3
40.04	24.0	31.5	39.46
46.71	17.26	23.78	32.21
54.46	11.53	16.69	23.72

**B = C<sub>7</sub>H<sub>5</sub>O.—(Continued)**

Wt. % B	$\varphi_0$	$\varphi_{10}$	$\varphi_{20}$
60.37	8.06	12.71	18.81
67.82	5.24	8.77	13.59
75.36	3.205	5.97	9.96
83.28	2.005	4.17	7.55
91.01	1.381	3.21	6.19
100.00	1.016	2.52	5.28

Wt. % B	$\varphi_{30}$	$\varphi_{40}$	$\varphi_{60}$
0.00	121.8	140.1	173.0
21.03	73.4	87.8	120.9
29.61	61.4	73.0	100.5
40.04	47.28	57.9	80.4
46.71	38.99	48.4	68.4
54.46	30.21	38.5	56.4
60.37	24.51	32.1	49.5
67.82	18.99	26.1	42.6
75.36	15.07	21.46	37.0
83.28	12.55	18.46	33.7
91.01	10.80	16.61	31.7
100.00	9.49	15.29	30.5

Wt. % B	$\varphi_{80}$	$\varphi_{110}$
0.00	205.3	259.7
14.06	165.8	217.2
27.48	133.9	181.4
41.10	104.7	147.8
54.03	81.3	121.6
63.11	68.4	106.4
71.88	59.0	95.5
81.72	52.9	89.3
89.95	51.0	90.0
100.00	51.6	92.5

**B = C<sub>8</sub>H<sub>5</sub>NO<sub>2</sub>, Phthalimide (33)**

Wt. % B	$\varphi_{25}$
5.05	101.2
11.93	84.6

**B = C<sub>8</sub>H<sub>14</sub>O<sub>3</sub>, Ethyl ethylacetate (35)**

	$\varphi_{25}$
0.00	113.3
12.70	106.9
40.62	90.8
63.99	78.9
85.33	67.1
100.00	59.6

**B = C<sub>10</sub>H<sub>18</sub>O<sub>3</sub>, Ethyl diethylacetate (35)**

	$\varphi_{25}$
0.00	113.6
2.83	111.5
6.91	108.4
21.10	98.5
50.83	74.2
100.00	35.8

**B = C<sub>11</sub>H<sub>11</sub>NO, Benzanilide (33)**

	$\varphi_{25}$
5.40	97.4
9.02	89.2
12.75	79.9

**B = C<sub>11</sub>H<sub>11</sub>N<sub>2</sub>O, 1, 2-Diphenylurea (33)**

	$\varphi_{25}$
5.69	95.7
7.19	92.7



B = C<sub>13</sub>H<sub>13</sub>N<sub>2</sub>S, 1, 2-Diphenylthiourea (33)

Wt. % B	$\varphi_{25}$
7.40	86.3
14.51	70.6

B = C<sub>14</sub>H<sub>9</sub>NO<sub>2</sub>, Phthalanil (33)

Wt. % B	$\varphi_{25}$
3.55	104.1

**C<sub>5</sub>H<sub>8</sub>O**

Ethyl propargyl ether

B = C<sub>7</sub>H<sub>14</sub>O<sub>2</sub>, Isoamyl acetate (60)

Wt. % B	$\varphi_{25}$
0.00	189.8
84.92	137.0
91.55	132.6
100.00	126.6

**C<sub>5</sub>H<sub>10</sub>O**

Ethyl allyl ether

B = C<sub>7</sub>H<sub>14</sub>O<sub>2</sub>, Isoamyl acetate (60)

Wt. % B	$\varphi_{25}$
0.00	289.7
89.42	143.3
94.36	135.1

**C<sub>5</sub>H<sub>10</sub>O<sub>2</sub>***n*-Propyl acetateB = C<sub>6</sub>H<sub>12</sub>O<sub>2</sub>, Isoamyl formate (78); cf. (55)

M % B	$\varphi_{12}$	$\varphi_{64}$
0.0	113.1	271.2
25.8	123.3	260.9
70.1	112.7	249.1
100.0	105.9	237.7

**C<sub>5</sub>H<sub>12</sub>O**

Isoamyl alcohol

B = C<sub>6</sub>H<sub>5</sub>NO<sub>2</sub>, Nitrobenzene (26)

Wt. % B	$\varphi_0$	$\varphi_{80}$
0.00	11.32	112.7
9.98	13.82	122.6
29.98	19.00	133.6
50.02	23.75	143.5
70.00	29.90	144.1
90.00	34.90	134.1
100.00	33.02	120.3

B = C<sub>6</sub>H<sub>6</sub>, Benzene (108)

g B/l	$\varphi_{18.4}$
549.5	104.6
708.0	132.6
761.9	139.1
799.4	144.05
857.0	146.8
864.4	147.0
864.6	148.7
872.0	148.1
880.0	148.1

B = C<sub>6</sub>H<sub>12</sub>O<sub>3</sub>, Paraldehyde (26)

Wt. % B	$\varphi_{10}$	$\varphi_{76.5}$
0.00	16.12	105.3
10.01	21.09	121.8
30.00	32.19	147.1
50.00	44.70	174.8
69.98	56.27	199.0
90.02	64.48	208.6
100.00	65.46	209.2

B = C<sub>6</sub>H<sub>14</sub>, Hexane (105)

g B/l	$\varphi_{18.7}$
0.0	21.2
540.4	207.4
570.0	226.5
647.1	272.1
653.4	275.4
662.8	285.2
666.0	287.3

B = C<sub>10</sub>H<sub>16</sub>N, Diethylaniline (26)

Wt. % B	$\varphi_0$	$\varphi_{76.5}$
0.00	11.32	105.2
9.97	13.22	
29.48	17.55	
30.00		127.6
49.92	22.13	138.2
69.56	26.17	141.1
89.96	27.78	138.0
100.00	26.05	127.7

**C<sub>5</sub>H<sub>12</sub>O**Ethyl *n*-propyl etherB = C<sub>7</sub>H<sub>14</sub>O<sub>2</sub>, Isoamyl acetate (60)

Wt. % B	$\varphi_{25}$
0.00	294.7
88.84	144.9
92.58	138.6

**C<sub>6</sub>H<sub>4</sub>Br<sub>3</sub>N**

2, 4, 6-Tribromoaniline

B = C<sub>7</sub>H<sub>14</sub>O<sub>2</sub>, Isoamyl acetate (139)

M A/l B	$\varphi_{25}$
0.71	98.3

**C<sub>6</sub>H<sub>4</sub>ClNO<sub>2</sub>***o*-ChloronitrobenzeneB = C<sub>12</sub>H<sub>11</sub>N, Diphenylamine (142)

M % B	$\varphi_{60}$
0.0	22.7
21.5	29.0
43.0	38.3
61.5	47.2
81.0	54.4
100.0	61.7

**C<sub>6</sub>H<sub>4</sub>Cl<sub>3</sub>N**

2, 4, 6-Trichloroaniline

B = C<sub>7</sub>H<sub>14</sub>O<sub>2</sub>, Iso (?) amyl acetate (139)

M A/l B	$\varphi_{25}$
0.71	101.5

**C<sub>6</sub>H<sub>5</sub>Br**

Bromobenzene

B = C<sub>6</sub>H<sub>5</sub>Cl, Chlorobenzene (78); cf. (55)

M % B	$\varphi_{12}$	$\varphi_{64}$
0.0	70.7	149.2
32.6	76.7	164.6
79.8	92.3	189.1
100.0	99.6	202.6

B = C<sub>6</sub>H<sub>6</sub>, Benzene (104); cf. (157)

$^{\circ}\text{C}$	$\varphi$
0	109.6
10	131.9
20	153.4
30	177.3
40	198.7
50	226.0
60	255.0
70	279.1
80	303.5

22.57 Wt. % A

$^{\circ}\text{C}$	$\varphi$
0.1	101.8
8.6	118.0
19.9	140.4
30.3	162.0
40.6	185.2
50.2	207.1
60.4	230.3
70.5	253.2

50.24 Wt. % A

$^{\circ}\text{C}$	$\varphi$
0.1	91.2
10.2	108.1
20.3	125.8
30.4	144.2
40.1	163.3
51.4	184.5
60.7	203.6
70.2	223.8

74.75 Wt. % A

$^{\circ}\text{C}$	$\varphi$
0.1	79.8
9.8	93.1
11.0	94.3
19.4	106.3
30.3	123.4
40.1	139.2
49.9	155.3
60.1	172.1
70.5	190.3

100 Wt. % A

$^{\circ}\text{C}$	$\varphi$
0	66.0
10	78.0
20	89.5
30	102.2
40	114.7
50	126.0
60	139.1
70	153.5
80	165.6

B = C<sub>7</sub>H<sub>8</sub>, Toluene; for data at 20, 35, and 50°C, v. (157).**C<sub>6</sub>H<sub>5</sub>Br<sub>2</sub>N**

Dibromoniline

B = C<sub>7</sub>H<sub>14</sub>O<sub>2</sub>, Isoamyl acetate (139); for M A/l = 0.71,  $\varphi_{25}$  = 96.1 for 2, 4-A; = 100.3 for 2, 6-A.**C<sub>6</sub>H<sub>5</sub>Cl**

Chlorobenzene

B = C<sub>6</sub>H<sub>6</sub>, Benzene (104) $^{\circ}\text{C}$  |  $\varphi$   
25.16 Wt. % A

$^{\circ}\text{C}$	$\varphi$
0.3	108.0
10.5	128.1
20.2	147.9
30.2	169.3
39.8	190.8
50.2	215.5
60.4	239.2
70.5	260.3
79.9	282.9

50.54 Wt. % A

$^{\circ}\text{C}$	$\varphi$
0.2	103.3
11.1	123.2
20.2	140.0
29.6	158.4
40.6	181.2
49.1	200.2
60.5	223.2
70.4	245.1
79.9	264.4

74.61 Wt. % A

$^{\circ}\text{C}$	$\varphi$
0.2	98.4
10.3	116.3
20.5	133.2
30.0	150.2
40.0	168.8
49.6	187.2
60.1	207.8
70.0	227.2
80.0	244.1

B = C<sub>6</sub>H<sub>5</sub>O, Phenol (17)

Wt. % B	$\varphi_{20}$
0.00	130.2
4.93	121.2
9.78	112.6
21.73	89.1
30.43	72.8
38.90	59.8
49.90	45.1
58.15	36.4
71.41	24.6
81.45	18.01
100.00	9.06

B = C<sub>7</sub>H<sub>8</sub>, Toluene; for data at 20, 35 and 50°C, v. (157).**C<sub>6</sub>H<sub>5</sub>ClO***o*-ChlorophenolB = C<sub>6</sub>H<sub>7</sub>N, Aniline (17)

Wt. % A	$\varphi_{10}$	$\varphi_{20}$	$\varphi_{30}$
0.00	15.87	23.36	31.80
15.54	11.07	17.30	24.69
28.94	7.60	12.92	19.76
40.16	5.60	10.42	16.86



**C<sub>6</sub>H<sub>5</sub>ClO**—(Continued)B = C<sub>6</sub>H<sub>7</sub>N—(Continued)

Wt. % A	$\varphi_{10}$	$\varphi_{20}$	$\varphi_{30}$
46.61	4.89	9.47	15.65
51.68	4.46	8.90	14.88
56.87	4.23	8.58	14.43
60.61	4.18	8.50	14.39
65.18	4.25	8.71	14.58
68.50	4.45	9.12	14.92
77.80	5.70	11.06	17.24
89.65	8.94	15.87	23.20
100.00	15.65	23.75	32.47
Wt. % A	$\varphi_{40}$	$\varphi_{60}$	$\varphi_{80}$
0.00	41.6	64.81	90.9
15.54	33.95	55.87	81.8
28.94	28.25	49.63	75.4
40.16	25.06	45.55	71.1
46.61	23.8	43.95	69.3
51.68	23.1	43.01	68.4
56.87	22.8	42.55	68.0
60.61	22.7	42.55	68.0
65.18	23.0	42.74	68.5
68.50	23.6	43.1	69.2
77.80	26.4	46.6	73.1
89.65	33.2	54.8	81.8
100.00	43.1	66.1	93.5

Wt. % A	$\varphi_{110}$	$\varphi_{150}$
0.00	141.0	224.2
15.54	128.0	200.8
28.94	118.8	185.5
40.16	112.9	176.1
46.61	111.0	173.3
51.68	110.0	171.8
56.87	109.6	170.9
60.61	109.6	170.9
65.18	110.2	171.2
68.50	111.0	172.1
77.80	114.6	174.8
89.65	122.0	178.9
100.00	131.6	183.2

Wt. % A	$\varphi_{25}$ (140)	$\varphi_{50}$ (140)
0.0	27.62	49.75
29.7	15.41	34.84
38.6	12.97	32.89
50.05	10.59	30.67
58.2	10.38	29.85
59.6	10.52	30.30
84.1	14.90	34.72
91.6	18.59	38.91
100.0	24.33	49.63

B = C<sub>6</sub>H<sub>5</sub>N<sub>2</sub>, Phenylhydrazine (140)

Wt. % B	$\varphi_{50}$
0.0	49.63
14.75	28.49
36.0	13.97
46.5	12.09
49.3	12.22
75.0	14.38
100.0	21.83

B = C<sub>7</sub>H<sub>14</sub>O<sub>2</sub>, Isoamyl acetate (136); for 80.2 Wt. % B,  $\varphi_{25} = 83.2$ .B = C<sub>8</sub>H<sub>11</sub>N, Dimethylaniline (17)

Wt. % B	$\varphi_0$	$\varphi_{10}$	$\varphi_{20}$
0.00	9.27	15.65	23.75
9.86	6.89	12.50	21.10
16.19	6.36	11.88	20.08
19.13	6.32	11.85	20.00
24.59	6.49	12.05	20.45
29.50	6.94	12.56	21.32
39.60	8.40	14.88	24.15
47.51	10.16	17.61	27.03
59.35	14.79	23.26	32.79
72.29	22.99	31.90	41.15
85.33	33.11	42.74	53.79
100.00	49.38	60.42	72.20

Wt. % B	$\varphi_{30}$	$\varphi_{40}$	$\varphi_{60}$
0.00	32.47	43.10	66.09
9.86	29.33	40.82	63.37
16.19	28.21	40.41	62.77
19.13	28.21	40.49	62.93
24.59	28.53	41.67	63.98
29.50	29.33	43.39	65.62
39.60	32.36	47.96	70.32
47.51	35.84	52.23	74.74
59.35	42.55	60.24	82.64
72.29	52.91	70.92	92.76
85.33	67.89	80.45	106.4
100.00	85.47	97.66	125.3

Wt. % B	$\varphi_{80}$
0.00	93.5
9.86	91.3
16.19	91.2
19.13	91.7
24.59	93.3
29.50	95.2
39.60	100.5
47.51	105.4
59.35	113.9
72.29	124.4
85.33	136.8
100.00	152.0

B = C<sub>8</sub>H<sub>7</sub>N, Quinoline (17)

Wt. % B	$\varphi_0$	$\varphi_{10}$	$\varphi_{20}$
0.00	9.268	15.65	23.75
13.34	2.542	5.501	10.05
27.82	0.746	2.077	4.576
36.58	0.408	1.241	3.163
42.08	0.332	1.083	2.730
45.06	0.331	1.080	2.685
46.72	0.342	1.109	2.710
49.69	0.392	1.214	2.849
51.19	0.444	1.299	2.990
57.16	0.889	1.988	4.233
67.47	2.410	4.503	7.690
83.21	6.897	10.526	15.11
100.00	14.64	20.83	27.47

Wt. % B	$\varphi_{30}$	$\varphi_{40}$	$\varphi_{60}$
0.00	32.47	43.10	66.09
13.34	15.60	23.09	41.24
27.82	7.80	13.09	27.06
36.58	5.74	10.00	22.10
42.08	5.30	9.18	20.49
45.06	5.26	9.11	20.28
46.72	5.26	9.13	20.24
49.69	5.44	9.32	20.41

B = C<sub>9</sub>H<sub>7</sub>N—(Continued)

Wt. % B	$\varphi_{30}$	$\varphi_{40}$	$\varphi_{60}$
51.19	5.58	9.55	20.66
57.16	6.94	11.16	22.73
67.47	10.98	15.75	27.82
83.21	20.53	26.95	42.02
100.00	34.01	41.93	59.84
Wt. % B	$\varphi_{80}$	$\varphi_{110}$	$\varphi_{150}$
0.00	93.5	131.6	183.2
13.34	62.5	99.3	153.8
27.82	45.35	79.0	131.8
36.58	39.06	70.9	121.6
42.08	37.04	68.1	117.6
45.06	36.04	66.9	116.3
46.72	35.91	66.6	115.6
49.69	36.04	66.4	115.2
51.19	36.23	66.4	115.1
57.16	38.54	68.4	116.7
67.47	45.01	75.0	122.7
83.21	59.77	88.6	134.2
100.00	80.00	107.5	150.2

B = C<sub>11</sub>H<sub>13</sub>N, Diphenylmethylamine (17)

Wt. % B	$\varphi_0$	$\varphi_{10}$	$\varphi_{20}$
0.00	9.27	15.65	23.75
10.38	9.07	14.97	22.73
20.66	8.83	14.31	21.79
31.24	8.55	13.70	20.88
42.42	8.22	13.04	19.92
49.48	8.00	12.58	19.23
61.65	7.51	11.83	18.08
74.10	6.85	11.01	16.81
86.17	6.18	10.15	15.46
100.00	5.45	9.13	13.79
Wt. % B	$\varphi_{30}$	$\varphi_{40}$	$\varphi_{60}$
0.00	32.47	43.10	66.09
10.38	32.11	41.84	63.49
20.66	29.76	40.16	61.05
31.24	28.49	38.46	58.47
42.42	27.14	36.36	55.71
49.48	26.29	35.09	54.05
61.65	24.81	32.89	50.89
74.10	23.23	30.77	47.39
86.17	21.58	28.57	43.96
100.00	19.49	26.04	40.32

Wt. % B	$\varphi_{80}$
0.00	93.5
10.38	89.3
20.66	84.7
31.24	80.8
42.42	76.9
49.48	74.2
61.65	70.4
74.10	66.7
86.17	62.8
100.00	57.6

**C<sub>6</sub>H<sub>5</sub>ClO***m*-ChlorophenolB = C<sub>6</sub>H<sub>7</sub>N, Aniline (140)

Wt. % A	$\varphi_{25}$	$\varphi_{50}$
0.0	27.62	47.62
24.6	16.31	37.74
39.9	12.33	31.15
59.7	9.23	24.81

B = C<sub>6</sub>H<sub>7</sub>N—(Continued)

Wt. % A	$\varphi_{25}$	$\varphi_{50}$
69.9	7.56	22.27
80.65	8.03	23.04
91.0	8.44	24.18
100.0	8.66	25.13

B = C<sub>7</sub>H<sub>14</sub>O<sub>2</sub>, Isoamyl acetate (136); for 80.2 Wt. % B,  $\varphi_{25} = 80.4$ .**C<sub>6</sub>H<sub>5</sub>ClO***p*-ChlorophenolB = C<sub>6</sub>H<sub>7</sub>N, Aniline (140)

Wt. % B	$\varphi_{25}$	$\varphi_{50}$
0.0	27.62	49.7
9.7	22.12	45.2
29.8	14.18	32.6
49.8	8.93	23.9
58.2	7.63	22.2
62.8	7.09	20.8
70.1	6.37	19.5
77.8	5.85	18.6
84.6	5.81	18.6
92.2	5.95	19.5
100.0		20.0

B = C<sub>7</sub>H<sub>14</sub>O<sub>2</sub>, Isoamyl acetate (136); for 80.2 Wt. % B,  $\varphi_{25} = 78.7$ .**C<sub>6</sub>H<sub>5</sub>Cl<sub>2</sub>N**

Dichloroaniline

B = C<sub>7</sub>H<sub>14</sub>O<sub>2</sub>, Isoamyl acetate (139); for M A/1 = 0.71,  $\varphi_{25} = 102.2$  for 2, 4-A; = 89.3 for 2, 6-A.**C<sub>6</sub>H<sub>5</sub>F**

Fluorobenzene

B = C<sub>6</sub>H<sub>6</sub>, Benzene (104)

°C	$\varphi$
25.78	Wt. % A
0.2	116.2
10.6	139.4
21.1	158.9
30.4	182.5
40.3	202.9
49.9	228.0
59.8	255.0
70.5	280.7
79.5	302.6
49.76	Wt. % A
0.3	121.6
9.7	142.3
19.8	161.9
30.5	186.2
40.2	206.2
50.1	230.6
60.1	257.0
69.8	279.9
80.2	305.0
75.04	Wt. % A
0.2	127.4
10.4	150.2
19.8	166.5
30.1	189.4
40.0	208.7



**B = C<sub>6</sub>H<sub>6</sub>—(Continued)**

°C	φ
75.04 Wt. % A	
50.0	232.2
60.3	257.9
70.7	282.6
79.8	304.8

**C<sub>6</sub>H<sub>5</sub>I**

Iodobenzene

**B = C<sub>6</sub>H<sub>6</sub>, Benzene (104)**

49.95 Wt. % A	
0.3	83.2
7.7	94.8
21.2	117.2
30.9	134.0
40.4	154.5
49.7	169.8
59.0	186.6
69.7	207.8

74.81 Wt. % A

0.1	61.3
8.6	75.9
22.1	93.9
30.5	105.2
40.3	119.2
50.1	134.1
61.0	155.0
69.4	163.3

**C<sub>6</sub>H<sub>5</sub>I<sub>2</sub>N**

Diiodoaniline

B = C<sub>7</sub>H<sub>15</sub>O<sub>2</sub>, Isoamyl acetate (139); for M A/1 = 0.71, φ<sub>11</sub> = 89.3.

**C<sub>6</sub>H<sub>5</sub>NO<sub>2</sub>**

Nitrobenzene

**B = C<sub>6</sub>H<sub>6</sub>, Benzene (108)**

g A/l	φ <sub>20</sub>
0	151.8
952	67.5
1088	56.7
1155	53.0
1183	51.3
1193	50.4
1199	50.2
1201	50.0
1205	49.9

°C

φ

50 Wt. % B (102)

0

25

40

55

70

Wt. % A

0.00

19.95

62.39

85.61

100.00

φ<sub>11</sub> (99)

166.9

146.8

98.3

69.6

54.5

**B = C<sub>6</sub>H<sub>5</sub>O, Phenol (17)**

Wt. % A	φ <sub>20</sub>
0.00	9.06
15.32	13.18

**B = C<sub>6</sub>H<sub>5</sub>O—(Continued)**

Wt. % A	φ <sub>20</sub>
29.97	18.5
41.36	23.9
50.27	28.3
62.04	35.15
72.59	40.6
81.88	45.3
91.16	49.0
95.84	50.6
100.00	51.8

**B = C<sub>6</sub>H<sub>7</sub>N, Aniline (77)**

M % A	φ <sub>0</sub>	φ <sub>24.2</sub>
0	9.79	39.8
10	13.53	
25	18.76	42.5
35	21.59	
45	24.89	46.5
50	25.80	
55	26.05	47.5
65	28.44	
75	29.47	49.3
90	30.95	49.3
100	31.11	48.9

M % A	φ <sub>65</sub>	φ <sub>92.8</sub>
0	56.2	72.2
25	61.8	79.6
45	64.1	80.1
55	64.8	80.1
75	64.1	79.5
90	64.0	78.0
100	64.2	77.4

**B = C<sub>6</sub>H<sub>11</sub>O<sub>3</sub>, Paraldehyde (105)**

g B/l	φ <sub>20</sub>
0.0	49.6
5.33	49.6
8.24	49.7
10.89	49.5
21.32	49.5
41.19	49.4
54.47	49.2
106.6	48.8
205.9	48.8
272.4	49.0

**B = C<sub>6</sub>H<sub>14</sub>, Hexane (25)**

°C	φ
0.0 Wt. % A	
16.35	310
18.55	313
20.00	314
21.40	319
23.22	323

24.2 Wt. % A

16.90	237
18.45	241
20.02	245
21.42	250
23.15	253

36.5 Wt. % A

17.42	182
17.50	195
17.70	195
18.55	196
20.50	203

**B = C<sub>6</sub>H<sub>14</sub>—(Continued)**

°C	φ
36.5 Wt. % A	
22.85	210
25.10	216
44.6 Wt. % A	
18.87	165
19.08	173
20.62	187
22.02	185
23.42	189
25.00	194

50.7 Wt. % A

19.40	133
20.50	143
21.60	154
23.70	161
25.20	165

54.2 Wt. % A

19.92	126
20.12	131
21.70	145
23.25	150
25.40	155

64.4 Wt. % A

18.30	116
18.75	120
20.95	125
22.90	129
24.92	134

70.8 Wt. % A

14.8	100
15.8	104
18.5	109
19.9	111
21.6	114
23.3	116
25.1	120

79.6 Wt. % A

15.09	84.7
16.67	87.0
18.44	89.3
20.51	91.7
22.73	95.2
24.30	97.1

100 Wt. % A

13.5	44.1
18.0	48.3
23.0	52.9
28.0	57.8
32.0	61.3
35.0	64.5

**B = C<sub>7</sub>H<sub>9</sub>N, o-Toluidine (78)**

M % B	φ <sub>11</sub>
0.00	40.9
33.34	37.9
50	32.8
66.67	27.6
100.00	16.7

**B = C<sub>8</sub>H<sub>11</sub>N, Dimethylaniline (78)**

M % B	φ <sub>11</sub>	φ <sub>77.6</sub>
0.00		148.3
25		163.5
32.13	50.0	

**B = C<sub>8</sub>H<sub>11</sub>N—(Continued)**

M % B	φ <sub>11</sub>	φ <sub>77.6</sub>
50	53.4	179.7
67		191.1
68.72	56.1	
100.00	61.3	204.0

**B = C<sub>8</sub>H<sub>11</sub>N, Ethylaniline (78)**

Wt. % B	φ <sub>11</sub>	φ <sub>77.6</sub>
26.2		160.6
50	41.8	167.5
80		175.1
100	33.6	170.7

**B = C<sub>10</sub>H<sub>8</sub>, Naphthalene (84, 85)**

M % B	φ <sub>20</sub>
0	125.8
20	123.8
30	122.6
50	119.6
70	117.2
80	115.7
90	114.2
100	112.9

**B = C<sub>10</sub>H<sub>15</sub>N, Diethylaniline (78)**

Wt. % B	φ <sub>11</sub>
33.19	40.1
50	39.3
66.66	36.7
100.00	30.7

**B = C<sub>10</sub>H<sub>20</sub>O, Menthol (132)**

Wt. % B	φ <sub>55.6</sub>	φ <sub>74.6</sub>
0.00	95.2	127.7
11.33	99.9	133.5
36.12	74.0	101.8
51.11	53.8	87.0
68.61	47.5	83.7
86.73	26.8	64.8
100.00	15.9	40.5

**B = C<sub>12</sub>H<sub>18</sub>O<sub>6</sub>, Diethyl diacetyl-tartrate (132)**

Wt. % B	φ
	67.30°C
0.00	113.3
24.80	75.3
52.45	49.7
70.91	35.9
82.95	20.3
92.74	14.0
100.00	11.17

82.2°C

0.00	137.4
24.80	100.5
52.45	70.6
70.91	50.5
82.95	32.4



**C<sub>6</sub>H<sub>5</sub>NO<sub>2</sub>—(Continued)****B = C<sub>12</sub>H<sub>18</sub>O<sub>8</sub>—(Continued)**

Wt. % B	φ
82.2°C	
92.74	24.6
100.00	18.17
99.0°C	
0.00	172.1
24.80	129.1
52.45	96.3
70.91	76.4
82.95	51.0
92.74	40.4
100.00	32.0

**C<sub>6</sub>H<sub>5</sub>NO<sub>2</sub>****o-Nitrophenol****B = C<sub>6</sub>H<sub>7</sub>N, Aniline (17, 154)**

Wt. % A	φ <sub>20</sub>	φ <sub>40</sub>
0.00	31.8	41.6
10.88	33.6	43.1
22.36	34.9	44.3
32.77	35.6	45.0
42.00	35.7	45.1
51.28	35.4	44.8
60.52	34.7	44.0
68.32	33.9	43.0
77.11	32.6	41.4
85.04	31.0	39.8
91.49	29.5	38.3
100.00	27.4	36.3
Wt. % A	φ <sub>60</sub>	φ <sub>80</sub>
0.00	64.8	90.9
10.88	66.1	91.4
22.36	67.3	92.1
32.77	67.7	92.5
42.00	67.7	91.9
51.28	66.9	90.9
60.52	65.6	88.7
68.32	63.9	86.6
77.11	61.6	83.4
85.04	59.2	80.1
91.49	57.4	77.6
100.00	52.8	74.2

**B = C<sub>7</sub>H<sub>7</sub>N, p-Toluidine (140)**

Wt. % B	φ <sub>80</sub>
0.0	37.3
20.4	46.5
64.7	54.5
100.0	55.6

**B = C<sub>9</sub>H<sub>7</sub>N, Quinoline (17)**

Wt. % B	φ <sub>20</sub>	φ <sub>40</sub>
0.00	27.40	36.30
4.46	29.32	35.03
8.82	25.32	33.84
13.24	24.45	32.69
17.59	23.70	31.74
22.44	22.96	30.77
32.96	21.77	29.33
41.80	21.19	28.82
50.84	21.37	28.86
58.39	22.25	29.63
69.31	24.24	31.65
78.57	26.52	34.15
89.20	29.75	37.59
100.00	34.01	41.93

**B = C<sub>9</sub>H<sub>7</sub>N—(Continued)**

Wt. % B	φ <sub>60</sub>	φ <sub>80</sub>
0.00	54.8	74.2
4.46	53.4	72.9
8.82	52.4	71.8
13.24	51.3	71.1
17.59	50.3	70.4
22.44	49.4	69.4
32.96	47.8	68.0
41.80	47.1	67.3
50.84	47.1	67.4
58.39	48.0	68.0
69.31	50.1	69.6
78.57	52.7	71.9
89.20	55.9	75.7
100.00	59.8	80.0

**B = C<sub>7</sub>H<sub>11</sub>O<sub>2</sub>, Isoamyl acetate (136); for 78.9 Wt. % B, φ<sub>25</sub> = 95.1 for o-A; = 69.0 for m-A; = 63.9 for p-A.**

**C<sub>6</sub>H<sub>6</sub>****Benzene****B = C<sub>6</sub>H<sub>6</sub>O, Phenol (110)**

Wt. % B	φ <sub>20</sub>
0.00	159.0
6.04	146.4
9.84	138.1
20.1	115.6
32.40	88.8
42.09	71.4
53.02	52.3
63.65	37.85
74.11	26.24
83.20	18.69
100.00	9.06

**B = C<sub>6</sub>H<sub>10</sub>O<sub>2</sub>, Ethyl acetate (35)**

Wt. % B	φ <sub>25</sub>
0.00	162.7
2.78	162.1
10.47	162.7
43.56	125.9
93.88	71.1
100.00	66.3

**B = C<sub>6</sub>H<sub>12</sub>, Cyclohexane; for data at 20°C, v. (152.2).**

**B = C<sub>6</sub>H<sub>12</sub>O<sub>3</sub>, Paraldehyde (105)**

g B/l	φ <sub>20</sub>
0.000	155.7
4.740	155.6
6.768	155.6
18.960	155.2
33.841	155.1
94.800	152.5
169.208	149.5
822.4	98.7
896.9	94.1
959.1	87.5
989.6	85.0
994.8	84.9

**B = C<sub>7</sub>H<sub>8</sub>, Toluene (50)**

Wt. % B	$\varphi_{15}$	$\varphi_{20}$	$\varphi_{25}$
0	142.1	154.1	165.0
25	160.3	171.2	179.9
50	158.5	167.5	176.7
75	152.7	164.7	174.2
100	159.5	170.6	180.8
Wt. % B	$\varphi_{30}$	$\varphi_{35}$	$\varphi_{40}$
0	177.9	189.8	203.3
25	190.5	200.8	211.9
50	188.3	199.2	210.1
75	185.5	197.6	208.3
100	192.3	202.8	214.6
Wt. % B	$\varphi_{70}$	$\varphi_{80}$	
0	284.9	305.8	
50	285.7		
100	287.4	314.5	

**Wt. % B****φ<sub>25</sub> (99)****0.00****8.44****33.42****69.41****89.01****100****50 Wt. % B (102)****°C****0****25****40****55****70****B = C<sub>7</sub>H<sub>8</sub>O, m-Cresol (78)**

M % B	φ <sub>12</sub>	φ <sub>14</sub>
0	137.9	270.8
25	80.9	189.5
50	34.0	144.9
75	12.15	93.9
100	3.37	54.8

**B = C<sub>8</sub>H<sub>8</sub>O, Acetophenone (18, 116)**

Wt. % B	φ <sub>16</sub>
0.00	145.8
21.83	122.0
36.23	113.5
55.26	87.9
71.50	72.7
87.26	60.8
100.00	50.2
Wt. % B	φ <sub>25</sub>
50	105.6
75	78.7
100	59.9

**B = C<sub>8</sub>H<sub>10</sub>O<sub>2</sub>, Ethyl ethylacetate (35)**

Wt. % B	φ <sub>25</sub>
0.00	162.7
17.75	149.0
24.98	141.3
36.13	129.4
100.00	60.0

**B = C<sub>9</sub>H<sub>7</sub>N, Quinoline (74)**

Wt. % B	φ <sub>25</sub>
0.00	165.0
15.83	128.1
23.33	122.0
32.44	106.9

**B = C<sub>9</sub>H<sub>7</sub>N—(Continued)**

Wt. % B	φ <sub>25</sub>
45.55	88.6
55.77	74.9
68.84	61.3
73.33	52.4
84.34	42.7
100.00	29.75

**B = C<sub>9</sub>H<sub>10</sub>O<sub>2</sub>, Ethyl benzoate (71)**

Wt. % B	Vol. % B	φ <sub>25</sub>
0.00	0.00	165.3
22.35	19.43	138.0
54.19	49.78	98.2
67.74	63.75	83.3
75.14	71.70	75.4
85.86	83.57	64.2
91.47	90.00	58.5
100.00	100.00	50.2

**B = C<sub>10</sub>H<sub>8</sub>, Naphthalene (71)**

Wt. % B	Vol. % B	φ <sub>25</sub>
0.00	0.0	165.3
8.11	7.3	152.3
17.16	15.2	137.7
22.97	20.6	129.8
28.82	25.8	121.0
34.10	30.8	114.1
37.69	33.9	109.0

**For data at 10–31°C, v. (74.1).**

**B = C<sub>10</sub>H<sub>12</sub>, 1, 2, 3, 4-Tetrahydronaphthalene; for data at 20°C, v. (152.2).**

**B = C<sub>10</sub>H<sub>18</sub>O<sub>2</sub>, Ethyl diethylacetate (35)**

Wt. % B	φ <sub>25</sub>
0.00	162.7
3.65	160.3
14.16	146.7
49.52	101.3
68.19	75.7
100.00	35.8

**B = C<sub>12</sub>H<sub>10</sub>, Diphenyl (71)**

Wt. % B	Vol. % B	φ <sub>25</sub>
0.00	0.0	165.3
18.08	15.8	131.8
30.57	27.3	110.9
53.03	48.9	77.0

**B = C<sub>14</sub>H<sub>12</sub>O<sub>2</sub>, Benzyl benzoate (14)**

Wt. % B	$\varphi_5$	$\varphi_{15}$	$\varphi_{25}$
0.0	120.5	142.5	166.1
25.0	76.4	92.8	110.3
50.0	42.4	48.0	53.7
75.0	18.9	25.0	32.5
100.0	5.18	8.25	12.06
Wt. % B	$\varphi_{40}$	$\varphi_{60}$	$\varphi_{80}$
0.0	203.5	257.9	301.8
25.0	138.8	179.3	212.7
50.0	66.0	86.1	115.6
75.0	45.9	64.3	82.0
100.0	19.07	30.7	44.6
Wt. % B	$\varphi_{90}$	$\varphi_{100}$	
50.0	139.3		
100.0	52.3	60.4	



**B = C<sub>18</sub>H<sub>32</sub>O<sub>4</sub>—(Continued)**

Wt. % B	Vol. % B	$\varphi_{25}$ (71)
0.0	0.0	165.4
38.71	33.08	83.6
65.60	59.91	43.45
79.17	74.84	27.90
90.73	88.44	18.25
95.88	94.78	14.53
100.00	100.00	11.83

**B = C<sub>18</sub>H<sub>32</sub>O<sub>4</sub>, sec.-Octyl hydrogen phthalate (36)**

Wt. % B	$\varphi_{25}$
<b>Racemic</b>	
5.86	147.8
8.24	139.1
10.61	133.0
14.95	118.6
15.28	116.2
18.29	108.8
<b>Dextro</b>	
6.18	146.1
10.71	132.0
11.16	131.0
19.44	105.0
<b>Levo</b>	
19.29	106.2

**C<sub>6</sub>H<sub>5</sub>BrN****Bromoaniline**

B = C<sub>7</sub>H<sub>14</sub>O<sub>2</sub>, Isoamyl acetate (139); for M A/l B = 0.71,  $\varphi_{25}$  = 103.5 for o-A; = 101.5 for p-A.

**C<sub>6</sub>H<sub>5</sub>ClN****Chloroaniline**

B = C<sub>7</sub>H<sub>14</sub>O<sub>2</sub>, Isoamyl acetate (139); for M A/l B = 0.71,  $\varphi_{25}$  = 108.1 for o-A; = 105.0 for m-A; = 104.3 for p-A.

**C<sub>6</sub>H<sub>5</sub>I****Iodoaniline**

B = C<sub>7</sub>H<sub>14</sub>O<sub>2</sub>, Isoamyl acetate (139); for M A/l B = 0.71,  $\varphi_{25}$  = 98.9.

**C<sub>6</sub>H<sub>5</sub>N<sub>2</sub>O<sub>2</sub>****Nitroaniline**

B = C<sub>7</sub>H<sub>14</sub>O<sub>2</sub>, Isoamyl acetate (139); for M A/l B = 0.71,  $\varphi_{25}$  = 98.8 for o-A; = 96.1 for m-A.

**C<sub>6</sub>H<sub>5</sub>O****Phenol**

B = C<sub>6</sub>H<sub>7</sub>N, Aniline (17)

Wt. % A	$\varphi_{20}$	$\varphi_{125}$
0.0	23.36	157.0
7.94	19.65	150.2
15.31	16.39	144.3

**B = C<sub>6</sub>H<sub>7</sub>N—(Continued)**

Wt. % A	$\varphi_{20}$	$\varphi_{125}$	
23.34	13.60	138.3	
31.28	11.25	133.5	
39.39	9.44	129.9	
47.56	8.23	126.9	
53.81	7.58	125.2	
62.50	7.05	123.3	
69.52	6.91	122.4	
77.02	7.04	122.2	
85.02	7.51	123.0	
92.28	8.19	125.5	
100.00	9.06	129.9	
Wt. % A	$\varphi_{20}$	$\varphi_{40}$	
0.00	31.8	41.6	
7.58	27.3	36.5	
15.96	28.0	27.7	
23.33	19.7	27.7	
31.65	16.8	24.4	
39.14	14.6	21.7	
47.14	13.0	19.6	
54.00	12.0	18.35	
61.84	11.2	17.45	
69.28	11.02	17.15	
76.86	11.25	17.45	
84.80	11.99	18.32	
92.50	13.02	19.6	
100.00	14.10	21.0	
Wt. % A	$\varphi_{60}$	$\varphi_{80}$	
0.00	64.9	90.9	
7.58	59.2	85.1	
15.96	53.2	78.1	
23.33	48.0	72.7	
31.65	43.8	67.6	
39.14	40.2	63.7	
47.17	37.45	60.17	
54.00	35.8	58.1	
61.84	34.5	56.6	
69.28	34.0	55.8	
76.86	34.25	56.3	
84.80	35.3	57.3	
92.50	37.2	59.9	
100.00	39.7	63.3	
Wt. % A	$\varphi_{85} (140)$		
0.00	36.6		
35.1	18.6		
51.4	15.3		
67.9	13.9		
79.7	14.4		
100.0	18.0		
M % A	$\varphi_{25}$ (77)	$\varphi_{54.5}$ (77)	$\varphi_{74}$ (77)
0	27.19	50.09	63.2
10	24.42	45.32	
25	20.25	38.45	52.6
32	17.75	36.15	50.2
40	15.92		
46	14.67	31.69	46.8
50	13.73	30.41	45.7
54	13.17	30.09	45.6
60	12.79	29.04	44.8
68	12.62	28.72	44.7
75	12.92	28.56	44.6
90	14.71	19.48	
100		30.60	45.6

**B = C<sub>6</sub>H<sub>5</sub>N<sub>2</sub>, Phenylhydrazine (140)**

Wt. % B	$\varphi_{50}$
0.0	31.2
20.2	19.05
40.2	13.36
50.1	12.47
53.7	12.20
62.8	12.42
80.4	15.26
100.0	21.83

**B = C<sub>7</sub>H<sub>9</sub>N, p-Toluidine (17)**

Wt. % B	$\varphi_{29.9}$	$\varphi_{59.9}$	$\varphi_{79.8}$
0.00	20.88	39.7	63.25
10.24	18.59	36.0	58.4
19.81	16.91	33.4	55.4
28.89	15.95	32.2	53.8
37.30	15.90	32.1	53.8
44.91	16.63	33.2	55.4
53.75	18.42	35.6	58.6
61.43	20.75	39.0	62.5
70.14	24.45	43.8	68.1
79.33	29.83	50.4	75.6
90.15	38.00	60.6	87.0
100.00	48.08	71.5	99.4

Wt. % B	$\varphi_{99.9}$	$\varphi_{125}$
0.00	89.7	129.9
10.24	85.4	124.1
19.81	82.6	120.5
28.89	80.6	118.1
37.30	80.3	117.5
44.91	81.6	118.8
53.75	85.1	122.0
61.43	89.1	126.6
70.14	95.2	133.5
79.33	103.2	141.6
90.15	115.1	152.7
100.00	130.6	164.5
Wt. % B	$\varphi_{160}$	$\varphi_{175}$
0.00	168.9	203.3
13.66	161.8	196.9
20.57	158.7	195.3
23.75	157.5	194.2
34.31	156.0	192.3
43.69	157.2	193.4
54.39	161.6	197.2
61.76	165.8	201.6
65.58	168.4	204.1
76.89	178.6	213.7
83.38	184.8	219.3
100.00	203.7	236.4

Wt. % B	$\varphi_{20}$ (140)
0.0	14.29
28.5	11.19
37.8	10.40
41.2	10.62
52.5	11.57
60.1	13.21

**B = C<sub>7</sub>H<sub>14</sub>O<sub>2</sub>, Isoamyl acetate (136)**

Wt. % B	$\varphi_{25}$
84.7	90.5

**B = C<sub>8</sub>H<sub>11</sub>N, Dimethylaniline (17)**

Wt. % B	$\varphi_{10}$	$\varphi_{20}$
0.00	4.975	9.06
7.24	5.09	9.20
14.61	5.40	9.71
21.86	6.10	10.64
30.03	7.42	12.48
37.18	9.14	14.82
44.25	11.51	17.73
51.73	14.37	21.28
59.61	18.81	26.53
66.92	23.89	32.4
76.06	31.80	41.4
82.70	38.67	48.9
90.93	48.17	59.4
100.00	60.46	72.1
Wt. % B	$\varphi_{29.8}$	$\varphi_{40.2}$
0.00	14.10	21.1
6.81	14.58	21.8
13.92	15.43	22.7
21.17	16.6	24.1
29.01	18.8	26.9
36.05	21.3	29.9
43.86	25.4	35.0
50.81	30.0	39.8
58.54	35.3	45.8
67.29	43.2	54.35
75.40	51.6	63.7
83.39	61.4	73.8
92.07	74.0	86.3
100.00	85.2	97.9
Wt. % B	$\varphi_{69.9}$	$\varphi_{80}$
0.00	39.5	63.1
6.81	37.5	63.8
13.92	42.0	65.7
21.17	44.0	67.9
29.01	47.6	72.5
36.05	51.0	76.2
43.86	56.8	82.4
50.81	63.0	89.4
58.54	70.0	97.6
67.29	78.9	106.7
75.40	89.0	117.4
83.39	99.9	127.9
92.07	113.9	141.4
100.00	125.2	152.0
Wt. % B	$\varphi_{126}$	$\varphi_{177}$
0.00	129.9	204.1
7.24	131.4	214.1
14.61	134.2	217.4
21.86	137.4	220.8
30.03	142.2	226.2
37.18	147.1	231.5
44.25	153.1	237.0
51.73	159.5	243.9
59.61	168.4	251.3
66.92	177.0	259.1
76.06	188.3	268.8
82.70	196.9	276.2
90.93	207.5	284.1
100.00	216.9	293.3



**C<sub>9</sub>H<sub>7</sub>O**—(Continued)**B = C<sub>9</sub>H<sub>7</sub>N**, Quinoline (17)

Wt. % B	$\varphi_{9.8}$	$\varphi_{20.1}$
0.00	4.98	9.06
7.94	4.13	7.48
16.63	3.17	6.02
23.12	2.61	5.15
31.79	2.11	4.30
39.70	1.90	3.95
46.80	1.97	4.08
54.92	2.67	4.92
62.48	3.78	6.65
70.24	5.96	9.45
77.27	8.55	12.74
85.44	12.35	17.47
92.46	16.16	21.77
100.00	20.81	27.51

Wt. % B	$\varphi_{29.9}$	$\varphi_{40}$
0.00	14.10	21.01
8.21	11.85	18.12
16.51	9.90	15.24
24.25	8.50	13.37
32.08	7.44	11.92
40.11	6.76	11.06
47.69	6.96	11.27
55.38	8.19	12.58
62.86	10.36	15.15
70.18	13.47	18.74
78.04	17.85	23.84
85.08	22.25	28.95
92.23	27.43	34.66
100.00	39.97	41.95

Wt. % B	$\varphi_{60}$	$\varphi_{80}$
0.00	39.68	63.3
8.21	34.78	56.0
16.51	30.17	49.3
24.25	26.95	45.0
32.08	24.39	41.4
40.11	22.73	38.7
47.69	22.94	38.3
55.38	24.39	39.7
62.86	27.43	43.3
70.18	32.05	48.3
78.04	38.24	55.3
85.08	44.54	62.4
92.23	51.28	70.2
100.00	59.84	80.0

Wt. % B	$\varphi_{128}$	$\varphi_{176}$
0.00	129.9	203.3
7.94	119.5	194.9
16.63	108.9	184.5
23.12	103.2	175.4
31.79	94.8	165.0
39.70	89.4	158.2
46.80	86.4	154.1
54.92	86.6	153.4
62.48	89.2	153.8
70.24	94.0	155.8
77.27	101.2	160.8
85.44	111.0	170.1
92.46	119.5	177.3
100.00	127.2	182.8

**B = C<sub>10</sub>H<sub>9</sub>N**,  $\alpha$ -Naphthylamine (140)

Wt. % B	$\varphi_{20}$	$\varphi_{60}$
0.0	14.29	31.2
52.0	4.02	11.7
56.5	3.72	11.11
79.1	3.09	9.17
92.5		8.85
100.0		8.93

**B = C<sub>12</sub>H<sub>11</sub>N**, Diphenylamine (17)

Wt. % B	$\varphi_{20}$	$\varphi_{40}$
0.00	14.10	21.10
7.96	13.78	20.64
15.41	13.48	20.1
23.40	13.07	19.5
31.16	12.64	18.9
40.35	12.08	18.15
46.57	11.61	17.6
53.44	11.14	16.9
61.40	10.56	16.1
69.13	9.97	15.3
76.71	9.33	14.4
84.82	8.58	13.5
92.13	7.96	12.6
100.00	7.37	11.8

Wt. % B	$\varphi_{61}$	$\varphi_{81}$
0.00	39.84	63.5
7.96	39.53	62.1
15.41	39.00	61.0
23.40	38.17	59.5
31.16	37.24	58.0
40.35	35.84	56.1
46.57	34.90	54.7
53.44	33.78	53.2
61.40	32.42	51.2
69.13	31.02	49.4
76.71	29.50	47.1
84.82	27.86	44.6
92.13	26.11	42.4
100.00	23.98	39.6

**Wt. % B**  $\varphi_{60}$  (140)

Wt. % B	$\varphi_{60}$
0.0	31.2
32.4	26.15
58.9	22.93
79.5	20.0

**B = C<sub>12</sub>H<sub>18</sub>O<sub>8</sub>**, Diethyl diacetyltartrate (132)

Wt. % B	$\varphi_{55.6}$	$\varphi_{67.3}$
0.0	39.9	57.4
30.87	34.7	49.6
55.45	19.5	30.0
68.37	12.0	18.9
84.38	10.26	16.3
94.58	8.24	14.3
100.00		11.17

Wt. % B	$\varphi_{82.2}$	$\varphi_{90}$
0.00	85.6	125.2
30.87	70.6	103.3
55.45	44.9	69.3
68.37	32.3	45.4
84.38	28.7	45.8
94.58	24.6	40.3
100.00	18.17	32.0

**B = C<sub>13</sub>H<sub>13</sub>N**, Diphenylmethylamine (17)

Wt. % B	$\varphi_{9.8}$	$\varphi_{20.1}$
0.00	4.98	9.06
10.70	5.33	9.54
21.21	5.71	10.65
32.90	6.20	10.69
43.13	6.66	11.30
51.58	7.09	11.83
63.08	7.66	12.53
72.31	8.16	13.09
82.82	8.73	13.70
90.52	9.12	13.99
95.08	9.17	14.12 (?)
100.00	9.12	13.85

Wt. % B	$\varphi_{30}$	$\varphi_{40}$
0.00	14.10	21.10
9.95	14.86	22.17
17.78	15.38	22.73
26.42	15.97	23.36
37.88	16.75	24.10
50.13	17.54	24.88
64.66	18.45	25.77
79.96	19.27	26.53
89.79	19.49	26.60
95.02	19.61	26.43
100.00	19.49	26.08

Wt. % B	$\varphi_{60}$	$\varphi_{80}$
0.00	39.53	63.09
9.95	40.08	63.05
17.78	40.49	63.09
26.42	40.90	62.93
37.88	41.41	62.74
50.13	41.75	62.38
64.66	42.11	61.58
79.96	42.19	60.61
89.79	41.67	59.45
95.02	41.07	58.55
100.00	40.32	57.64

**C<sub>6</sub>H<sub>7</sub>N**

Aniline

**B = C<sub>6</sub>H<sub>12</sub>**, Cyclohexane (25) $^{\circ}\text{C}$   $\varphi$ 

0 Wt. % A

17	97.1
22	107.5
27	116.3
32	126.6
35	133.3

28.45 Wt. % A

30.6	93.5
31.0	97.1
33.0	102.0
35.0	107.5
37.0	112.4

42.85 Wt. % A

31.0	65.8
32.5	78.1
34.0	87.0
36.0	94.3
37.0	96.2

45.63 Wt. % A

31.5	70.4
32.5	76.9
36.0	87.7

**B = C<sub>6</sub>H<sub>12</sub>**—(Continued) $^{\circ}\text{C}$   $\varphi$ 

45.63 Wt. % A

37.0 90.1

52.1 Wt. % A

29.6 60.2

31.0 68.0

32.0 71.4

35.0 78.7

37.0 82.0

58.75 Wt. % A

31.6 66.2

31.9 67.6

32.4 69.4

33.6 71.9

36.5 78.7

72.78 Wt. % A

27.9 52.6

30.0 55.9

33.0 60.6

36.0 65.4

100 Wt. % A

19.0 22.4

23.0 25.8

26.0 28.4

29.0 31.2

32.0 34.1

35.5 37.6

**B = C<sub>6</sub>H<sub>5</sub>IN**, Aniline hydroiodide (120)

Wt. % B	$\varphi_{25}$
0.00	27.5
2.04	25.2
4.21	22.2
9.04	17.8
14.05	13.5
18.00	11.4
20.48	9.73

**B = C<sub>7</sub>H<sub>8</sub>**, Toluene (86)

Wt. % B	$\varphi_{88}$	$\varphi_{100}$
25	168.6	200
50	226	256
75	293	330

**B = C<sub>7</sub>H<sub>8</sub>O**, *m*-Cresol (77)

M % B	$\varphi_0$	$\varphi_{34.1}$	$\varphi_{64}$
0	9.79	34.43	57.71
10	7.18	29.47	52.74
25	4.23	22.17	46.69
35	2.87	18.77	43.59
45	1.95	15.97	40.60
50	1.66	14.78	
55	1.49	13.98	37.85
65	1.22	12.80	36.37
75	1.12	12.27	35.53
90	1.09	12.14	34.60
100	1.19	12.34	35.90

M % B	$\varphi_{76.3}$	$\varphi_{91.9}$
0	64.60	77.11
25	54.92	69.08
45	49.42	63.49
55	47.53	60.93
75	45.51	59.37
90	45.32	58.93
100	45.85	58.99



**B = C<sub>7</sub>H<sub>8</sub>O.—(Continued)**

M % B	$\varphi_{25}$ (144)
0.0	26.87
30.0	14.71
37.4	12.20
46.1	10.39
54.9	8.993
63.1	8.20
77.8	8.12
100.0	7.75

**B = C<sub>7</sub>H<sub>8</sub>O, *p*-Cresol (140)**

Wt. % B	$\varphi_{25}$	$\varphi_{30}$
0.0	27.62	49.7
30.0	14.39	34.1
53.6	9.35	25.2
62.7	8.06	23.5
79.5	6.94	21.6
90.0	6.90	21.2
100.0		21.6

**B = C<sub>7</sub>H<sub>8</sub>O<sub>2</sub>, Isoamyl acetate (139)**

M A/l B	$\varphi_{25}$
0.71	113.1

**B = C<sub>8</sub>H<sub>10</sub>O, Phenetole (17)**

Wt. % B	$\varphi_{25}$	$\varphi_{30}$	$\varphi_{35}$
0.00	9.95	15.85	23.47
11.74	12.52	19.12	27.47
21.75	15.27	22.57	31.55
32.30	18.25	26.67	36.4
43.68	22.17	31.15	41.8
54.66	26.39	36.2	47.6
65.69	31.20	41.9	54.4
76.54	36.76	48.2	61.4
88.49	44.15	56.2	70.0
100.00	53.76	65.4	80.6

Wt. % B	$\varphi_{25}$
0.00	90.9
11.74	98.7
21.75	105.9
32.30	114.0
43.68	122.8
54.66	131.9
65.69	141.6
76.54	151.8
88.49	165.8
100.00	179.2

**C<sub>6</sub>H<sub>8</sub>N<sub>2</sub>**

Phenylenediamine  
B = C<sub>7</sub>H<sub>10</sub>O<sub>2</sub>, Isoamyl acetate (139); for 0.71 M A/l B,  $\varphi_{25}$  = 99.1 for *m*-A; = 101.7 for *o*-A.

**C<sub>6</sub>H<sub>10</sub>O**

Mesityl oxide

B = C<sub>7</sub>H<sub>14</sub>O<sub>2</sub>, Isoamyl acetate (31)

Wt. % B	$\varphi_{25}$
86.85	134.0
91.42	131.7

**C<sub>6</sub>H<sub>10</sub>O<sub>3</sub>**

Ethyl acetoacetate

B = C<sub>7</sub>H<sub>8</sub>N, 2, 6-Lutidine (35)

Wt. % B	$\varphi_{25}$
0.00	112.5
10.9	107.6
32.63	98.2
52.01	87.3
88.55	69.5
100.00	65.1

**C<sub>6</sub>H<sub>10</sub>O<sub>4</sub>**Dimethyl *d*-tartrateB = C<sub>6</sub>H<sub>10</sub>O<sub>4</sub>, Dimethyl *dl*-tartrate (138)

Wt. % B	$\varphi_{25}$
0	7.52
50	7.63
100	7.69

**C<sub>6</sub>H<sub>14</sub>**

Hexane

B = C<sub>10</sub>H<sub>18</sub>, 1, 2, 3, 4-Tetrahydronaphthalene; for data at 20°C, *v.* (182.2).B = C<sub>10</sub>H<sub>18</sub>, Decane (Disoamyl) (16)

Wt. % B	Vol. % B	$\varphi_{25}$	$\varphi_{35}$
0.00	0.00	304.0	353.6
35.50	33.17	228.9	269.2
62.28	59.82	181.0	216.3
100.00	100.00	120.8	149.2

Wt. % B	$\varphi_{25}$	$\varphi_{35}$
0.00	403.8	459.2
35.50	312.6	356.5
62.28	254.6	294.2
100.00	180.5	213.4

**C<sub>7</sub>H<sub>7</sub>NO**

Benzaldoxime

B = C<sub>7</sub>H<sub>14</sub>O<sub>2</sub>, Isoamyl acetate (137); for M A/kg = 0.25,  $\varphi_{25}$  = 119.4 for  $\alpha$ -A; = 118.5 for  $\beta$ -A.**C<sub>7</sub>H<sub>7</sub>NO<sub>2</sub>***m*-NitrotolueneB = C<sub>12</sub>H<sub>18</sub>O<sub>2</sub>, Diethyl diacetyl tartrate (132)

Wt. % B	$\varphi$
0.00	115.3
25.92	72.2
49.32	49.4
67.74	30.9
80.77	21.8
92.18	13.2
100.00	11.17

**B = C<sub>12</sub>H<sub>18</sub>O<sub>2</sub>—(Continued)**Wt. % B |  $\varphi$   
 $t = 82.2^\circ\text{C}$ 

0.00	140.5
25.92	88.9
49.32	68.2
67.74	45.2
80.77	34.1
92.18	23.2
100.00	18.17

 $t = 99.0^\circ\text{C}$ 

0.00	175.3
25.92	117.2
49.32	96.0
67.74	65.5
80.77	53.0
92.18	37.2
100.00	32.0

**C<sub>7</sub>H<sub>8</sub>**

Toluene

B = C<sub>7</sub>H<sub>8</sub>O, *m*-Cresol (78)

M % A	$\varphi_{12}$	$\varphi_{24}$
0	3.37	54.8
25	12.1	91.4
50	40.0	154.3
75	88.3	215.3
100	132.7	268.1

B = C<sub>8</sub>H<sub>10</sub>O<sub>2</sub>, Ethyl benzoate (71); *cf.* (99)

Wt. % B	Vol. % B	$\varphi_{25}$
0.00	0.00	181.2
22.67	19.51	146.1
47.26	42.56	110.2
73.51	69.64	78.2
81.90	78.90	68.9
89.85	87.98	60.4
100.00	100.00	50.25

B = C<sub>10</sub>H<sub>8</sub>, Naphthalene (71)

Wt. % B	Vol. % B	$\varphi_{25}$
0.0	0.0	181.0
5.73	4.8	171.1
13.72	11.8	156.4
20.12	17.4	145.6
27.31	24.1	133.9

For data at 10–31°C, *v.* (74.1).B = C<sub>12</sub>H<sub>10</sub>, Diphenyl (71)

0.0	0.0	181.2
21.38	18.6	136.3
32.02	28.2	116.4
38.97	34.8	103.9

B = C<sub>14</sub>H<sub>12</sub>O<sub>2</sub>, Benzyl benzoate (71)

0.00	0.00	181.2
41.69	35.58	84.5
63.11	56.93	49.6
81.09	76.82	27.7
89.60	86.94	19.7
95.41	94.16	15.0
100.00	100.00	11.83

B = C<sub>10</sub>H<sub>16</sub> (?), Turpentine (99)

Wt. % B	$\varphi_{25}$
0.00	185.5
24.91	164.7

**B = C<sub>10</sub>H<sub>16</sub>—(Continued)**

Wt. % B	$\varphi_{25}$
46.30	142.6
79.35	102.2
93.21	83.9
100.00	74.5

**C<sub>7</sub>H<sub>8</sub>O**

Benzyl alcohol

B = C<sub>7</sub>H<sub>14</sub>O<sub>2</sub>, Isoamyl acetate (136)

Wt. % A	$\varphi_{25}$
17.2	96.6

**C<sub>7</sub>H<sub>8</sub>O***m*-CresolB = C<sub>7</sub>H<sub>8</sub>N, *o*-Toluidine (78)

M % B	$\varphi_{12}$	$\varphi_{24}$
0	3.37	54.8
25	2.97	53.2
50	3.92	58.4
75	8.12	74.9
100	17.22	101.7

B = C<sub>7</sub>H<sub>14</sub>O<sub>2</sub>, Isoamyl acetate (136); for 17.2 Wt. % A,  $\varphi_{25}$  = 85.9 for *o*-A; = 85.7 for *m*-A; = 85.5 for *p*-A.B = C<sub>8</sub>H<sub>11</sub>N, Dimethylaniline (78)

M % B	$\varphi_{25}$	$\varphi_{35}$	$\varphi_{77}$
0	2.47	54.8	71.7
25		68.0	
26.9	6.65		77.3
50	11.8	98.3	
65.1	21.3		138.3
75			138.3
100	58.0	165.7	202.8

**C<sub>7</sub>H<sub>8</sub>O**

Anisole

B = C<sub>7</sub>H<sub>14</sub>O<sub>2</sub>, Isoamyl acetate (136)

Wt. % A	$\varphi_{25}$
17.2	121.0

**C<sub>7</sub>H<sub>9</sub>N**

Toluidine

B = C<sub>7</sub>H<sub>14</sub>O, Isoamyl acetate (139); for M A/l B = 0.71,  $\varphi_{25}$  = 113.1 for *o*-A; = 113.4 for *m*- and *p*-A.**C<sub>7</sub>H<sub>9</sub>NO***o*-AnisidineB = C<sub>7</sub>H<sub>14</sub>O<sub>2</sub>, Isoamyl acetate (139)

M A/l	$\varphi_{25}$
0.71	108.5



$C_7H_{14}O_2$ Isoamyl acetate	
B = $C_8H_6$ , Phenylacetylene (60)	
Wt. % B	$\varphi_{25}$
0.00	126.6
7.43	126.4
100.00	113.3
B = $C_8H_7NO_3$ , Piperonal oxime (137); for M B/kg = 0.25, $\varphi_{24.70}$ = 113.0 for $\alpha$ -B; = 109.2 for $\beta$ -B.	
B = $C_8H_8$ , Phenylethylene (60)	
Wt. % B	$\varphi_{25}$
0.00	126.6
4.70	125.9
100.00	90.2
(1)	
8.39	124.6
B = $C_8H_8O$ , Acetophenone (31)	
4.31	124.7
8.28	122.3
B = $C_8H_8O_2$ , Phenyl acetate (136)	
20.7	107.3
B = $C_8H_8O_3$ , Mandelic acid (36)	
Wt. % dl-B	$\varphi_{25}$
6.12	95.4
7.64	90.9
9.86	84.2
12.88	74.9
Wt. % l-B	$\varphi_{25}$
4.72	100.1
7.93	89.4
8.55	87.0
11.39	78.1
B = $C_8H_7NO_3$ , Anisaldoxime (137); for M B/kg = 0.25, $\varphi_{24.70}$ = 115.7 for $\alpha$ -B; = 114.6 for $\beta$ -B.	
B = $C_8H_{10}$ , Phenylethane (60)	
Wt. % B	$\varphi_{25}$
0.00	126.6
7.43	129.9
100.00	164.6
B = $C_8H_{10}O$ , Methyl benzyl ether (136)	
19.0	117.9
B = $C_8H_{10}O$ , Phenetole (136)	
19.0	117.0
B = $C_8H_{10}O$ , Methyl tolyl ether (136); for 19.0 Wt. % B, $\varphi_{25}$ = 115.5 for $\alpha$ -B; = 113.8 for $m$ -B; = 116.3 for $p$ -B.	
B = $C_8H_8O_3$ , Phenylpropionic acid (60)	
Wt. % B	$\varphi_{25}$
2.86	116.7
3.81	113.3
5.80	105.7
7.16	100.4

B = $C_9H_7BrO_2$ , <i>cis</i> -Allo-1-bromocinnamic acid (137)	
M B/kg	$\varphi_{24.70}$
0.25	115.2
B = $C_9H_7BrO_2$ , <i>trans</i> -1-Bromocinnamic acid (137)	
0.25	114.7
B = $C_9H_8O_2$ , Cinnamic acid (60)	
Wt. % B	$\varphi_{25}$
3.89	112.1
5.02	108.1
B = $C_9H_{10}O_2$ , $\beta$ -Phenylpropionic acid (60)	
Wt. % B	$\varphi_{25}$
4.01	115.5
5.75	110.2
B = $C_9H_{10}O_2$ , Benzyl acetate (136)	
22.4	102.7
B = $C_9H_{10}O_3$ , Ethyl hydroxybenzoate (136); for 24.2 Wt. % B, $\varphi_{25}$ = 95.7 for $\alpha$ -B; = 63.0 for $m$ -B.	
B = $C_9H_{11}NO_3$ , Ethyl <i>p</i> -aminobenzoate (139)	
M B/l A	$\varphi_{25}$
0.71	88.5
B = $C_9H_{11}NO_3$ , Ethyl anthranilate (139)	
0.71	100.8
B = $C_9H_{14}O$ , Phorone (31)	
Wt. % B	$\varphi_{25}$
8.24	122.9
14.90	119.8
B = $C_{10}H_8O$ , Naphthol (136); for 21.7 Wt. % B, $\varphi_{25}$ = 64.6 for $\alpha$ -B; = 62.6 for $\beta$ -B.	
B = $C_{10}H_8N$ , Naphthylamine (139); for 0.71 M B/l A, $\varphi_{25}$ = 97.0 for $\alpha$ -B; 97.1 for $\beta$ -B.	
B = $C_{10}H_{10}O$ , Benzylideneacetone (31)	
Wt. % B	$\varphi_{25}$
5.12	117.8
9.12	110.5
B = $C_{10}H_{10}O_2$ , Safrol (31)	
16.45*	104.4
6.54	120.1
27.30	99.1
B = $C_{10}H_{12}O$ , Benzylacetone (31)	
3.65	123.4
7.92	120.1
B = $C_{10}H_{12}O_3$ , Eugenol (31)	
12.26	103.2
19.61	90.4
7.66*	108.7
14.51*	94.16

\* Iso-B.

B = $C_{10}H_{15}NO$ , Carvoxime (138); for 85.8 Wt. % B, $\varphi_{25}$ = 90.2 for <i>d</i> -B; = 90.0 for <i>dl</i> -B; for 100 Wt. % B, $\varphi_{25}$ = 21.01 for <i>d</i> -B; = 21.10 for <i>dl</i> -B.	
B = $C_{12}H_{10}$ , Diphenyl (31)	
Wt. % B	$\varphi_{25}$
2.94	124.5
4.32	123.1
B = $C_{12}H_{11}N$ , Diphenylamine (139)	
M B/l A	$\varphi_{25}$
0.71	93.4
B = $C_{12}H_{12}O$ , Cinnamylideneacetone (31)	
Wt. % B	$\varphi_{25}$
1.50	125.6
2.47	123.7
B = $C_{13}H_{10}O$ , Benzophenone (31)	
5.74	117.5
6.48	115.6
B = $C_{13}H_{12}N_2$ , Benzaldehyde phenylhydrazone (137); for 0.25 M B/kg, $\varphi_{24.70}$ = 113.8 for $\alpha$ -B; = 111.98 for $\beta$ -B.	
B = $C_{13}H_{12}O$ , Diphenyl carbinol (136)	
Wt. % B	$\varphi_{25}$
26.1	66.8
B = $C_{13}H_{20}O_3$ , Menthyl propiolate (60)	
5.37	114.9
B = $C_{14}H_{10}$ , Diphenylacetylene (60)	
4.17	120.3
B = $C_{14}H_{11}NO_2$ , Benziloxime (137); for 0.25 M B/kg, $\varphi_{24.70}$ = 107.5 for $\alpha$ -B; = 106.3 for $\beta$ -B.	
B = $C_{14}H_{12}$ , Diphenylethylene (60)	
Wt. % B	$\varphi_{25}$
1.39	124.4
4.70	119.1
B = $C_{14}H_{14}$ , Diphenylethane (60)	
4.37	120.9
5.29	119.9
B = $C_{15}H_{12}O$ , Benzylideneacetophenone (60)	
4.00	117.9
5.45	114.7
B = $C_{15}H_{14}O$ , Benzylacetophenone (31)	
3.99	120.5
5.10	117.8
B = $C_{15}H_{14}O$ , Diphenylacetone (31)	
4.28	120.2
4.84	119.6

B = C <sub>10</sub> H <sub>14</sub> , Diphenylbutadiene (60)		
Wt. % B	φ <sub>25</sub>	
2.06	120.8	
2.44	121.1	
B = C <sub>10</sub> H <sub>18</sub> , Diphenylbutane (60)		
1.44	124.0	
3.40	117.3	
B = C <sub>17</sub> H <sub>14</sub> O, Dibenzylideneacetone (31)		
2.15	121.1	
2.76	119.4	
B = C <sub>17</sub> H <sub>14</sub> O, Cinnamylideneacetophenone (31)		
2.10	122.0	
3.31	118.4	
B = C <sub>18</sub> H <sub>24</sub> O <sub>3</sub> , <i>l</i> -Menthyl <i>dl</i> -mandelate		
Wt. % B	°C (138)	φ
14.0	25	90.1
100.0	85	15.3
B = <i>l</i> -Menthyl <i>L</i> -mandelate		
14.0	25	92.2
100.0	85	15.8
B = C <sub>18</sub> H <sub>34</sub> O <sub>2</sub> , Oleic acid (137)		
M B/kg	φ <sub>24.70</sub>	
0.25	104.7	
B = C <sub>18</sub> H <sub>34</sub> O <sub>2</sub> , Elaidic acid (137)		
0.25	102.7	
B = C <sub>19</sub> H <sub>30</sub> O <sub>2</sub> , Menthyl cinnamate (60)		
Wt. % B	φ <sub>25</sub>	
1.20	124.4	
6.08	111.6	
18.48	82.5	
B = C <sub>19</sub> H <sub>30</sub> O <sub>2</sub> , Menthyl β-phenylpropionate (60)		
5.88	114.6	
9.38	108.5	
B = C <sub>20</sub> H <sub>38</sub> O <sub>2</sub> , Ethyl elaidate (137)		
M B/kg	φ <sub>24.70</sub>	
0.25	109.3	
B = C <sub>20</sub> H <sub>38</sub> O <sub>2</sub> , Ethyl oleate (137)		
0.25	108.0	
B = C <sub>21</sub> H <sub>18</sub> O, Dicinnamylideneacetone (31)		
Wt. % B	φ <sub>25</sub>	
0.89	124.4	
0.01	123.9	
C <sub>8</sub> H <sub>10</sub> <i>o</i> -Xylene		
B = C <sub>8</sub> H <sub>10</sub> , <i>m</i> -Xylene (78)		
M % B	φ <sub>15</sub>	φ <sub>64</sub>
0.0	105.2	229.1
27.1	112.1	237.1
73.1	121.5	250.2
100.0	126.8	255.2



B = C <sub>8</sub> H <sub>10</sub> , <i>p</i> -Xylene (78)		
M % B	$\varphi_{12}$	$\varphi_{64}$
0.0	105.2	229.2
18.5	110.0	234.6
68.1	118.7	249.0
100.0	125.5	257.1

C <sub>8</sub> H <sub>10</sub> <i>m</i> -Xylene		
B = C <sub>8</sub> H <sub>10</sub> , <i>p</i> -Xylene (78)		
M % B	$\varphi_{12}$	$\varphi_{64}$
0.0	126.7	255.2
24.6	125.2	258.2
70.8	125.1	257.8
100.0	125.6	257.1

B = C <sub>8</sub> H <sub>11</sub> N, Dimethyl-aniline (78)		
M % A	$\varphi_{12}$	$\varphi_{64}$
0.0	63.5	165.9
28.7	78.3	185.7
73.4	105.9	229.7
100.0	126.7	255.2

C <sub>8</sub> H <sub>10</sub> O Phenetole		
B = C <sub>8</sub> H <sub>10</sub> O, Phenyl ether (73)		
M % B	$\varphi_{25}$	
0.00	86.36	
9.94	76.40	
18.73	68.92	
29.63	61.27	
39.98	53.70	
48.95	47.71	
62.69	40.73	
67.47	38.03	
79.28	33.30	
86.33	30.63	
100.00	25.88	

C <sub>9</sub> H <sub>10</sub> O <sub>2</sub> Ethyl benzoate		
B = C <sub>9</sub> H <sub>10</sub> O <sub>2</sub> , Benzyl benzoate (73)		
M % B	$\varphi_{12}$	$\varphi_{64}$
0.00	49.65	
10.37	42.17	
19.77	36.37	
30.94	30.78	
40.59	26.74	
49.46	23.22	
60.55	20.21	
70.27	17.56	
75.25	16.37	
84.51	14.50	
95.35	12.44	
100.00	11.74	

C <sub>10</sub> H <sub>8</sub> Naphthalene		
B = C <sub>10</sub> H <sub>8</sub> O, <i>l</i> -Menthyl (132)		
Wt. % B	$\varphi_{82.2}$	$\varphi_{99.0}$
0.00	137.6	179.2
19.40	117.1	156.4
35.87	126.8	170.0
54.17	102.5	139.7

B = C <sub>10</sub> H <sub>20</sub> O.—(Continued)		
Wt. % B	$\varphi_{82.2}$	$\varphi_{99.0}$
69.89	87.5	131.0
84.76	75.7	123.8
92.63	63.7	109.5
100.00	54.0	96.1

B = C <sub>12</sub> H <sub>18</sub> O <sub>8</sub> , Diethyl diacetyltartrate (132)		
Wt. % B	$\varphi_{82.2}$	$\varphi_{99}$
0.00	137.6	179.2
31.74	72.78	99.1
52.89	63.82	89.4
69.49	47.26	71.2
82.34	27.84	43.2
91.9	25.57	42.4
100.00	18.17	32.0

C <sub>10</sub> H <sub>12</sub> O Anethole		
B = C <sub>10</sub> H <sub>20</sub> O, Menthol (132)		
Wt. % B	$\varphi_{55.6}$	$\varphi_{74.6}$
0.00	77.7	108.9
9.90	78.4	111.0
34.60	68.4	91.0
53.01	60.3	101.1
67.87	46.97	84.4
84.85	28.44	55.2
100.00	15.91	40.5

C <sub>10</sub> H <sub>12</sub> O		
Wt. % B	$\varphi_{82.2}$	$\varphi_{99.0}$
0.00	123.2	163.4
9.90	125.2	166.4
34.60	116.7	151.5
53.01	111.0	164.2
67.87	102.0	148.2
84.85	69.83	109.3
100.00	54.05	96.1

C <sub>10</sub> H <sub>14</sub> O <sub>8</sub> Dimethyl diacetylacetate		
B = C <sub>10</sub> H <sub>14</sub> O <sub>8</sub> , Dimethyl diacetyltartrate (9)		
Wt. % B	$\varphi_{26}$	
0	16.52	
10	16.76	
40	16.17	
60	16.17	
90	16.76	
100	16.12	

C <sub>12</sub> H <sub>10</sub> N <sub>2</sub> Azobenzene		
B = C <sub>12</sub> H <sub>11</sub> N, Benzylidene-aniline (19)		
B = C <sub>14</sub> H <sub>12</sub> , Stilbene (19)		
B = C <sub>14</sub> H <sub>14</sub> , Dibenzyl (19)		

C <sub>13</sub> H <sub>11</sub> N Benzylideneaniline		
B = C <sub>13</sub> H <sub>13</sub> N, Benzylaniline (19)		
B = C <sub>14</sub> H <sub>12</sub> , Stilbene (19)		

C <sub>14</sub> H <sub>12</sub> Stilbene		
B = C <sub>14</sub> H <sub>14</sub> , Dibenzyl (19)		

## THREE-COMPONENT SYSTEMS

CH <sub>3</sub> NO Formamide			
B = C <sub>2</sub> H <sub>5</sub> O, Ethyl alcohol C = C <sub>4</sub> H <sub>12</sub> IN, Tetramethylammonium iodide (63)			
Wt. % B in (A + B)	$\varphi_{15}$	$\varphi_{25}$	$\varphi_{35}$
0 M C/I			
25	29.51	38.80	48.40
50	40.19	51.57	63.29
75	56.79	70.82	85.18
0.1 M C/I			
25	28.83	37.72	46.90
50	38.90	49.95	61.31
70	54.70	67.84	80.84
0.25 M C/I			
25	27.48	36.19	44.88
50	37.51	47.94	58.58

C <sub>3</sub> H <sub>6</sub> O Acetone		
B = C <sub>4</sub> H <sub>10</sub> O, Ethyl ether C = C <sub>6</sub> H <sub>6</sub> , Benzene (13)		
$\varphi_{10}$	$\varphi_{20}$	$\varphi_{30}$
100 Wt. % C		
131.9	154.7	178.7
100 Wt. % B		
386.0	426.5	469.4
100 Wt. % A		
278.8	309.6	342.3
49.39 Wt. % A; 20.54 Wt. % B; 30.07 Wt. % C		
252.8	286.1	318.0

C <sub>4</sub> H <sub>5</sub> NS Allyl thiocyanate		
B = C <sub>6</sub> H <sub>7</sub> N, Aniline C = C <sub>7</sub> H <sub>8</sub> , Toluene (86)		
M % B	$\varphi_{86}$	$\varphi_{100}$
25 M % C		
0	296.7	324.7
7.5	227.3	251.9
15.0	149.2	165.3
22.5	83.54	96.15
30.0	43.25	58.79
37.5	32.08	44.95
39.0	34.17	47.78
52.5	78.80	99.6
67.5	137.7	167.8
75.0	168.6	199.6
50 M % C		
0	315.5	350.9
5.0	274.0	304.9
15.0	156.0	179.2
20.0	114.7	140.4
24.0	100.8	127.4
25.0	94.7	120.3
26.0	103.5	127.9
30.0	124.8	152.0

B = C <sub>6</sub> H <sub>7</sub> N; C = C <sub>7</sub> H <sub>8</sub> .— (Continued)		
M % B	$\varphi_{86}$	$\varphi_{100}$
50 M % C		
35.0	153.4	182.5
45.0	204.9	235.8
50.0	226.2	255.8
75 M % C		
0	333.3	357.1
2.5	312.5	352.1
7.5	251.3	284.9
10.0	227.3	264.6
12.0	216.9	251.3
12.5	212.8	248.8
13.0	222.2	257.1
15.0	234.2	268.1
17.5	246.9	279.3
20.0	293.3	330.0

C <sub>6</sub> H <sub>6</sub> Benzene		
B = C <sub>6</sub> H <sub>7</sub> N, Aniline C = C <sub>7</sub> H <sub>8</sub> O, <i>m</i> -Cresol (76)		

B = C <sub>7</sub> H <sub>8</sub> O, <i>m</i> -Cresol C = C <sub>8</sub> H <sub>11</sub> N, Dimethylaniline (79)		
Wt. % A	Wt. % B	$\eta/\eta_{\infty}$
	100	29.1
0.00	90.50	23.8
8.70	82.60	12.55
17.60	74.80	7.05
36.30	57.60	2.87
56.10	39.80	1.41
77.00	21.00	0.856
	81.40	18.4
8.75	74.00	9.8
17.70	66.90	5.85
36.50	51.60	2.50
56.40	35.40	1.34
77.50	18.30	0.86
	71.60	12.9
8.80	65.30	7.61
17.90	58.90	4.74
36.70	45.30	2.24
56.50	31.10	1.27
77.60	16.00	0.83
	51.90	6.05
8.90	47.50	4.08
18.10	42.60	2.94
46.90	27.60	1.34
78.00	11.30	0.796
	26.50	2.51
9.10	24.10	2.02
18.30	21.60	1.68
47.50	14.00	1.05
78.20	5.80	0.76
0.00	0.00	1.28



## LITERATURE

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## VELOCITY OF VAPORIZATION (AND GAS EVOLUTION) AND OF CONDENSATION (AND GAS ABSORPTION)

A. C. EGERTON

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## EVAPORATION IN VACUO

## GENERAL FORMULA

$$m = \alpha p (M/2\pi RT)^{1/2} \quad (28, 41); \text{ see further Vol. I, p. 91.}$$
 $m$  = mass in grams vaporized per cm<sup>2</sup> per sec.

 $p$  = vapor pressure at  $T$ , °K.

 $M$  = gram-molecular weight.

 $R$  = gas constant.

 $\alpha = 1 - \nu$ , where  $\nu$  is the fraction of molecules reflected without condensation ("accommodation coefficient").

## EVAPORATION FROM HOT FILAMENTS

For more recent critical compilation, *v.* (83.5)

Substance	$\log_{10} m$ (for $p$ in mm Hg and $\alpha = 1$ )	Range, °K	Lit.
Carbon*	14.19 - 47 000/ $T$ -1.25 $\log T$	3 100-3 800	(1, 77)
Molybdenum.....	17.11 - 38 600/ $T$ -1.76 $\log T$	2 000-2 400	(46)
Platinum.....	14.00 - 27 800/ $T$ -1.76 $\log T$	1 680-2 000	(46)
Tungsten†.....	9.42 - 45 450/ $T$	2 000-3 000	(18, 19, 41, 83)
Calcium‡.....	10.978 - 10 350/ $T$	770-970	(59)

\* See (1);  $\alpha$  varies with adsorption layer.

† Zwikker gives  $\log_{10} m = 11.92 - 48 400/T - 0.368 \log_{10} T - 0.00016T$ ; Langmuir gives  $\log_{10} m = 15.402 - 47 440/T - 1.4 \log_{10} T$  (M. P. 3540°K); Forsythe in close agreement with Zwikker's equation; Fonda's value at 2825°K lies between those of Langmuir and of Zwikker. For small crystals  $m$  is 30 % greater than for large (18). In  $N_2$ ,  $m$  is 6 % of the value in *vacuo*; 3.9 % in argon (18). Rosenhain and Ewen (63) found the following ratio of  $m$  for coarse and for fine crystals: Zn, 2.3; Ag, 1.2; Cu, 1.4.

‡ Formula deduced from vapor pressure formula given by Pilling for  $\alpha = 1$ ; the measurements of  $p$  included allowance for value of  $\alpha$  obtained by comparative measurements with Zn and Cd (59).

## EVAPORATION THROUGH AN APERTURE

If the diameter of the aperture is  $\geq 0.1$  of the mean free path,  $m$  is the same as from a free surface,  $\alpha = 1$ . Measurements have been made by this method for Cd, Hg, K, Na, Pb, Zn and benzophenone (13, 35, 62, 73).

## EVAPORATION OF SMALL DROPS (74, 75)

Spherical drop (see general formula for evaporation in *vacuo*).

For a drop of mercury resting on plane,  $m = -1.11 \frac{dr}{dt} \times \rho$ , where  $\rho$  is the density of mercury and  $\frac{dr}{dt}$  is the rate of change of radius with time.

## ACCOMMODATION COEFFICIENTS

VALUES OF  $\alpha$  FOR SATURATED VAPORS

Substance	$\alpha$	$t$ , °C	Lit.
Hg (liquid).....	1.00 $\pm$ 0.01	60 to -30	(37, 74, 75)
Hg (solid).....	0.85	-64	(74, 75)
Cd (solid).....	0.98 $\pm$ 0.2	(ca. 200)	(4, 14)
Th, Ta, W.....	1.0	(ca. 2000)	(42)
Benzophenone.....	0.2 to 0.5		(73)

VALUES OF  $\alpha$  FOR GASES ON VARIOUS SOLIDS (36, 43, 64)

Gas	Polished Pt*		Pt black at 20°C	W at 1500°K	Glass at 0°C
	°C	$\alpha$			
H <sub>2</sub> .....	-190	0.42	0.71	0.19	0.26
	0	0.26			
CO <sub>2</sub> .....	20	0.86	0.96		
O <sub>2</sub> .....	20	0.83	0.95		
N <sub>2</sub> .....	20	0.87		0.60	
He.....	-100	0.49			
	+200	0.38			
A.....	30-260	0.85			
Ne.....		0.65			

\* Soddy and Berry found same results for Pd as for Pt surface.

## CONDENSATION IN VACUO

OBSERVED TEMPERATURE REGION FOR IRREVERSIBLE

CONDENSATION

Substance	On glass, $t$ , °C	Lit.	Substance	$t$ , °C	Lit.
NH <sub>4</sub> Cl.....	< -183	(39)	Cd on paraffin.....	-70	(9)
Hg*	-140 to		Cd on mica.....	-80	(9)
	-130	(39, 81)	Cd on glass.....	-90	(81)
Zn*	-183 to		Vapor at 280°.....	-110	(16)
Cd*	-78	(39)	Vapor at 365°.....	-50	(16)
Mg.....					



OBSERVED TEMPERATURE REGION FOR IRREVERSIBLE  
CONDENSATION.—(Continued)

Substance	On glass, <i>t</i> , °C	Lit.	Substance	On glass, <i>t</i> , °C	Lit.
Cu.....	350 to 575	(39)	Ag*.....	< 575	(39)
			I <sub>2</sub> .....	-60	(39)

\* Cf. (15, 44).

Substance (16); cf. (38, 44, 78)	Vapor pressure, mm Hg	<i>t</i> , °C	Latent heat of adsorption, g-cal/g
Cd on glass.....	0.008	-107	5200
	0.03	-86	
Cd on copper.....	0.008	-111	2940
	0.03	-83	
Cd on silver.....	0.008	-86	3540
	0.03	-66	
Hg on silver.....	0.0083	-120	2560
	0.033	-88	

Although vaporization occurs according to the cosine law (38, 81), and for Ag, Zn, Sb<sub>2</sub>S<sub>3</sub>, and S (40), condensation is directed in the case of Cd, Hg, Zn and As but not HgI<sub>2</sub> or S, *v.* (23, 71, 72, 75).

## EVAPORATION IN STILL AIR AND OTHER GASES

## THEORETICAL EQUATIONS (66)

For values of diffusion coefficients, *v.* p. 62.

From flush circular area:

$$V = 4r\Delta \log_e \frac{p - p_0}{p - p_s}$$

when  $p_s$  is small,  $V = Kp_s/p$  [Dalton (11)].  $V$  = rate of evaporation (volume per unit time),  $p_s$  = saturation pressure at surface of liquid,  $p_0$  = pressure of vapor in gas at distance from surface,  $p$  = total gas pressure,  $r$  = radius of circular area,  $\Delta$  = diffusion coefficient (50, 58, 66, 80).

From elliptical area ( $a$  and  $b$  = axes of ellipse) approximate formula:

$$V = 4\sqrt{ab}\Delta \log_e \frac{p - p_0}{p - p_s} \quad (58, 60, 66).$$

From circular vessels (surface distant  $h$  below rim):

$$V = 4(\sqrt{h^2 + r^2} - h) \Delta \log_e \frac{p - p_0}{p - p_s} \quad (6, 47, 68, 69, 70, 80).$$

From vertical tube (distance from upper end of tube to surface of liquid in the tube, greater than the diameter):

$$V = \frac{A\Delta}{h} \log_e \frac{p - p_0}{p - p_s}$$

$A$  = area of cross section of tube,  $h$  = distance from upper end to surface (48, 52, 69, 79).

From spherical drop:

$$V = 4\pi r\Delta \log_e \frac{p - p_0}{p - p_s} \quad (65)$$

or

$$m = 4\pi r\Delta \frac{Mp_s}{RT} \quad (45) \quad \left(\text{for small values } \frac{p_s}{p}\right)$$

$m$  = mass evaporated per unit time;  $M$  = mol. wt.;  $r$  = radius of sphere, *v.* (84, 85).

The references refer to experimental work on the subject; the formulae hold only under ideal conditions. The essential conditions are adequacy of rate of supply of heat to maintain temperature of the surface (48) and absence of disturbance of the atmosphere in the neighborhood of the evaporating liquid (50, 58).

## EVAPORATION OF SMALL DROPS

I<sub>2</sub> in air:  $dm/dt = 1.83 \times 10^{-7}$  ( $r$  radius of drop;  $m$  = g cm<sup>-3</sup> (54, 84)).

Hg in air:  $dr/dt = 1.4 \times 10^{-10}$ , cm/sec for drops 10<sup>-4</sup> to 10<sup>-3</sup> cm radius. [Evaporation of small drops is checked by oxidation of droplet, *v.* (51)].

H<sub>2</sub>O: Evaporation of small drops less than 10<sup>-4</sup> cm radius checked by absorption of gases other than hydrogen (24).

## CHANGE IN RADIUS WITH TIME

Minutes	Air	H <sub>2</sub> , 70 %; Air, 30 %
5	$0.89 \times 10^{-4}$ cm	$0.99 \times 10^{-4}$ cm
20	$0.86 \times 10^{-4}$ cm	$0.90 \times 10^{-4}$ cm
45	$0.86 \times 10^{-4}$ cm	$0.74 \times 10^{-4}$ cm

## PLATINUM METALS IN AIR

Loss in weight, g/cm<sup>2</sup>/sec in air at atmospheric pressure (7)

<i>t</i>	Pt	Pt + 1 % Ir	Pt + 2.5 % Ir	Pt + 8 % Rh
900	0	0	0	0
1000	$2.2 \times 10^{-7}$	$8.3 \times 10^{-7}$	$1.6 \times 10^{-6}$	$1.9 \times 10^{-7}$
1200	$2.2 \times 10^{-6}$	$3.3 \times 10^{-6}$	$7.0 \times 10^{-6}$	$1.5 \times 10^{-6}$

Crookes (10) found the following percentage loss of total weight at 1300°C in air but did not mention extent of surface: 8 hr, Ru, 25 %; 22 hr, Ir, 7.3 %; 30 hr, Pd, 0.745 %; Pt, 0.245 %; Rh, 0.131 %. (In case of Ru and Ir oxidation occurred. Ir in *vacuo* at 1300°C lost 0.069 % in 30 hr.)

## EVAPORATION IN A CURRENT OF GAS

In steady horizontal wind (velocity  $W$ ):

$$V = k\sqrt{W} \quad \text{and} \quad V = \alpha r^{1.5}$$

$k$  and  $\alpha$ , constants (circular area of radius  $r$ , areas 250 m<sup>2</sup> to 10 cm<sup>2</sup> or in gentle draughts 25 m<sup>2</sup> to 1 cm<sup>2</sup>) (33, 68). For very large areas, see especially (21).

Numerous meteorological formulae connect evaporation with temperature, hygrometric and wind conditions (see annotated bibliography (49)).

General form:  $dE/dt = A(p_s - p_d) + B(p_s - p_d)W$  (Dalton-Weilermann).

$E$ , fall of level due to evaporation in time,  $t$ ;  $p_s$ , saturation pressure at temperature of surface;  $p_d$ , saturation pressure at dew point;  $W$ , wind velocity;  $A$  and  $B$ , constants, *v. also* (53).

Typical formula:  $E_{mm} = 0.425 (p_s - p_d) (1 + 0.805W)$  (Fitz-Gerald);  $W$  measured in km/hr (up to 20 km/hr).  $p$  in mm. See especially (5, 17, 61, 67).

Similar formulae are used for chemical engineering purposes; e.g., evaporation from pans in still air:  $M = 0.02 (p_s - p_d)^{1.5}$  (29).

Evaporation from pans in air current:

$$M = (0.031 + 0.0135W)(p_s - p_d) \frac{p_0}{p_1}$$

$M$  kg m<sup>-2</sup>hr<sup>-1</sup>;  $W$  = air velocity m/sec from 0.5 to 4 m/sec;  $p_0$  = 760 mm and  $p_1$  = barometric pressure; range 20 – 70°C (28.5, 29, 31).

## Notes

Rate of evaporation of water approximately proportional to vapor pressure up to (B. P. – 15°) (3).

At 50°C evaporation of water in a current of air ( $W = 2.5$  m/sec) is 2.8 times as rapid as in still air, and for  $W = 5$  m/sec, 3.8 times (3).

Number of gram-molecules of a liquid evaporated per unit time and unit surface is proportional to vapor pressure, *v.* (26, 30); for evaporation of toluene, nitrobenzene, *m*-xylene, and chlorobenzene in wind tunnel, *v. also* (69).

Evaporation from large areas (lakes, etc.) about two-thirds evaporation from small pans.

Evaporation of sea water approximately 5 % less than fresh water.

Evaporation of ocean approximately 820 mm per annum (34, 82).



## VAPOR PRESSURE BY STREAMING METHOD

$$\log_e \frac{p_s}{p_s - p} = \frac{\text{const.}}{\sqrt{W}}$$

where  $W$  is velocity of gas stream and  $p$  is partial pressure of vapor in gas.

Dependence of velocity of vaporization on pressure, temperature and nature of gas (27, 32). For measurements on Ag, Tl, Pb and Sn, *v.* (76).

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## THE VELOCITY OF DISSOLVING OF CRYSTALS IN LIQUIDS

R. G. VAN NAME

The velocity constant  $K$  has usually the value given by equation I or II. As recorded in the tables it has the dimensions [ $\text{cm min}^{-1}$ ] and is independent of the unit of concentration. In cases where it has been necessary to give the constant in the author's or arbitrary units, it is designated by  $K_{\text{arb}}$ .

For the case of simple solution in a solvent (reversible)

$$K = \frac{v}{S(C_s - C)} \frac{dC}{dt} = \frac{v}{S(t_2 - t_1)} \ln \frac{C_s - C_1}{C_s - C_2} \quad (\text{I})$$

in which  $v$  = volume in  $\text{cm}^3$ ,  $t$  = time in min,  $S$  = surface of contact in  $\text{cm}^2$ ,  $C$  = concentration at time  $t$ ,  $C_s$  = concentration at saturation, and  $\ln$  = log<sub>e</sub>.

For the case of solution by interaction with a dissolved reagent

$$K = -\frac{v}{SC} \frac{dC}{dt} = \frac{v}{St} \ln \frac{C_0}{C} \quad (\text{II})$$

in which  $C_0$  and  $C$  are the concentrations of the reagent at time zero and time  $t$ , respectively; other symbols as in I.

Since  $K$  depends upon the intensity of the stirring and upon the form and dimensions of the apparatus, a quantitative comparison of the results of different investigators is usually impossible.

The velocities of dissolving of metals in acids are subject to various disturbing effects, such as passivity, period of induction, large influence of physical state and of traces of certain impurities, evolution of gas, etc., and are often not expressible by definite velocity constants. The results obtained are frequently too complicated and difficultly reproducible to justify their inclusion in the following tables. In the case of magnesium, however, the disturbing effects seem to be of minor importance.

La constante de vitesse  $K$  a ordinairement la valeur donnée par l'équation I ou II. Dans les tables elle a la dimension [ $\text{cm min}^{-1}$ ] et elle est indépendante de l'unité de concentration. Dans les cas où il a été nécessaire de donner la constante dans les unités arbitraires de l'auteur, elle est désignée par  $K_{\text{arb}}$ .

Pour le cas d'une simple dissolution dans un solvant (reversible)

$$K = \frac{v}{S(C_s - C)} \frac{dC}{dt} = \frac{v}{S(t_2 - t_1)} \ln \frac{C_s - C_1}{C_s - C_2} \quad (\text{I})$$

où  $v$  = volume en  $\text{cm}^3$ ,  $t$  = temps en min,  $S$  = surface de contact en  $\text{cm}^2$ ,  $C$  = concentration au temps  $t$ ,  $C_s$  = concentration à la saturation et  $\ln$  = log<sub>e</sub>.

Pour le cas d'une dissolution par réaction avec un réactif dissout

$$K = -\frac{v}{SC} \frac{dC}{dt} = \frac{v}{St} \ln \frac{C_0}{C} \quad (\text{II})$$

où  $C_0$  et  $C$  sont respectivement les concentrations du réactif au temps zéro et au temps  $t$ ; pour les autres symboles comme en I.

Comme  $K$  dépend de l'intensité de l'agitation et de la forme et des dimensions de l'appareil, une comparaison quantitative des résultats obtenus par différents expérimentateurs est ordinairement impossible.

Les vitesses de dissolution des métaux dans les acides sont sujets à des effets perturbateurs variés, tels que: la passivité, la période d'induction, la grande influence de l'état physique et des traces de certaines impuretés, l'évolution du gaz, etc., et de la sorte ne peuvent souvent pas être exprimées par des constantes de vitesse définies. Les résultats obtenus sont fréquemment trop compliqués et difficilement reproductibles pour justifier leur publication dans les tables suivantes. Cependant, dans le cas du magnésium, les effets parasites paraissent être d'importance moindre.



Die Geschwindigkeitskonstante  $K$  hat gewöhnlich den nach Gleichung I oder II sich ergebenden Wert und wie aus den Tabellen folgt, besitzt sie die Dimension  $[\text{cm min}^{-1}]$  und ist von der Einheit der Konzentration unabhängig. In Fällen wo es nötig war die Konstante in den vom Autor gegebenen, oder in sonst willkürlichen, Einheiten anzuführen, wird sie mit  $K_{\text{arb.}}$  bezeichnet.

Für den Fall der einfachen reversiblen Lösung in einem Lösungsmittel gilt

$$K = \frac{v}{S(C_s - C)} \frac{dC}{dt} = \frac{v}{S(t_2 - t_1)} \ln \frac{C_s - C_1}{C_s - C_2} \quad (\text{I})$$

wo  $v$  = Volumen in  $\text{cm}^3$ ,  $t$  = Zeit in Minuten,  $S$  = Kontaktoberfläche in  $\text{cm}^2$ ,  $C$  = Konzentration zur Zeit  $t$ ,  $C_s$  = Sättigungskonzentration und  $\ln = \log_e$ .

Für den Fall der Wechselwirkung mit einem gelösten Stoff, hat man

$$K = -\frac{v}{SC} \frac{dC}{dt} = \frac{v}{St} \ln \frac{C_0}{C} \quad (\text{II})$$

Es bedeutet,  $C_0$  und  $C$  die Konzentration des reagierenden Bestandteiles zur Zeit Null bzw. zur Zeit  $t$ . Die anderen Zeichen sind die gleichen wie bei I.

Da  $K$  von der Rührgeschwindigkeit, der Form und der Dimension des verwendeten Apparates abhängt, ist ein quantitativer Vergleich der Ergebnisse der verschiedenen Beobachter meist nicht möglich.

Die Lösungsgeschwindigkeit der Metalle in Säuren unterliegt den verschiedenen störenden Einflüssen, wie Passivität und Induktionsdauer. Bedeutend ist der Einfluss des physikalischen Zustandes der Probe, der Spuren von Verunreinigungen, der Gasentwicklung, u.s.w. Dies alles ist nicht durch eine bestimmte Geschwindigkeitskonstante ausdrückbar. Die Ergebnisse sind häufig zu kompliziert und zu schwer reproduzierbar um in diese Tafeln aufgenommen zu werden. Beim Magnesium scheinen sich jedoch die störenden Einflüsse weniger bemerkbar zu machen.

Generalmente il valore della costante di velocità  $K$  è quello dedotto dalle equazioni I o II. Questa velocità, come è indicato nelle tabelle, ha le dimensioni di  $[\text{cm min}^{-1}]$  ed è indipendente dalla unità di concentrazione. Nei casi in cui si è dovuto dare la costante in unità arbitrarie, quelle adoperate dagli autori, essa è stata indicata con  $K_{\text{arb.}}$ .

Nel caso che si tratti di semplice dissoluzione in un solvente (reversibile)

$$K = \frac{v}{S(C_s - C)} \frac{dC}{dt} = \frac{v}{S(t_2 - t_1)} \ln \frac{C_s - C_1}{C_s - C_2} \quad (\text{I})$$

nella quale  $v$  = volume in  $\text{cm}^3$ ,  $t$  = tempo in minuti,  $S$  = superficie di contatto in  $\text{cm}^2$ ,  $C$  = concentrazione al tempo  $t$ ,  $C_s$  = concentrazione al punto di saturazione e  $\ln = \log_e$ .

Nel caso di dissoluzione con reazione con una sostanza disciolta si ha:

$$K = -\frac{v}{SC} \frac{dC}{dt} = \frac{v}{St} \ln \frac{C_0}{C} \quad (\text{II})$$

nella quale  $C_0$  e  $C$  rappresentano le concentrazioni della sostanza reagente al tempo 0 ed al tempo  $t$ , mentre gli altri simboli hanno lo stesso significato che nella I.

Poichè  $K$  dipende dalla intensità della agitazione, dalla forma e dalle dimensioni dell'apparecchio, è impossibile confrontare quantitativamente i risultati dei vari sperimentatori.

Le velocità di dissoluzione dei metalli negli acidi risentono molto della azione di varie cause perturbatrici, come ad esempio: passività, periodo di induzione, stato fisico, presenza di tracce di certe impurezze, svolgimento di gas, ecc., e perciò spesso non sono esprimibili con valori ben definiti delle costanti. Spesso i risultati ottenuti sono troppo complessi e difficili a riprodursi per poter essere compresi nelle tabelle che seguono. Nel caso del magnesio tuttavia sembra che le cause perturbatrici non abbiano molta importanza.

## VELOCITY CONSTANTS

### 1. SALTS IN WATER

Rotary stirring, 400 r.p.m.; exposed surface horizontal, below stirrer; 25°C (30)

Salt	$C_s$ , * g/100 g H <sub>2</sub> O	$K$ , cm/min
KI.....	146.45	0.186
KBr.....	67.75	0.171
KCl.....	36.32	0.147
NaCl.....	35.92	0.105
TlCl.....	0.385	0.204†
TlBr.....	0.057	0.144†
PbCl <sub>2</sub> .....	1.08	0.060†
PbBr <sub>2</sub> .....	0.974	0.078†
BaCl <sub>2</sub> ·2H <sub>2</sub> O.....	36.9	0.096
K <sub>2</sub> SO <sub>4</sub> .....	12.04	0.102
K <sub>4</sub> Fe(CN) <sub>6</sub> ·3H <sub>2</sub> O.....	32.0	0.048†
FeSO <sub>4</sub> ·7H <sub>2</sub> O.....	29.7	0.048
NiSO <sub>4</sub> ·7H <sub>2</sub> O.....	39.6	0.033
CoSO <sub>4</sub> ·7H <sub>2</sub> O.....	37.8	0.036
ZnSO <sub>4</sub> ·7H <sub>2</sub> O.....	57.9	0.030
MgSO <sub>4</sub> ·7H <sub>2</sub> O.....	38.3	0.030
CuSO <sub>4</sub> ·5H <sub>2</sub> O.....	22.29	0.039
CdSO <sub>4</sub> · $\frac{1}{2}$ H <sub>2</sub> O.....	77.0	0.021
CaSO <sub>4</sub> ·2H <sub>2</sub> O.....	0.210	0.021‡

\* Calculated as anhydrous salt. † ‡ to cleavage surface.  
† Fused salt used. ‡ Selenite, ‡ to face (010).

### 2. SALTS IN WATER

Rotary stirring, 50 r.p.m.; whole crystal exposed (12).

Salt	$C_s$ , g/100 g soln.	$K_{\text{arb.}}$ , 4.8°C	$C_s$ , g/100 g soln.	$K_{\text{arb.}}$ , 30.1°C
K <sub>2</sub> SO <sub>4</sub> .....	7.82	0.027	11.43	0.071
NaClO <sub>3</sub> .....	45.47	0.043	51.22	0.083
K <sub>2</sub> Cr <sub>2</sub> O <sub>7</sub> .....	5.52	0.026	15.17	0.069

### 3. METALS IN DISSOLVED IODINE (AND BROMINE)

Disk of metal 40 mm diameter, 0.6 mm thick, supported vertically, whole surface exposed. Rotary stirring, 240 r.p.m.;  $S = 2.60 \text{ cm}^2$ , but velocity per unit area not accurately calculable on account of difference in stirring on the two sides of the disk. Aqueous solution of I<sub>2</sub> (resp. Br<sub>2</sub>) in KI (resp. KBr); 25 ± 0.1°C (27)\*.

Metal	Salt, mole/l, I <sub>2</sub> in KI	$K \times S$ , cm <sup>2</sup> /min	Metal	Salt, mole/l, I <sub>2</sub> in KI	$K \times S$ , cm <sup>2</sup> /min
Hg.....	0.6	8.81	Zn.....	1.2	9.64
Cd.....	0.6	8.69	Hg.....	2.4	10.48
Zn.....	0.6	8.64	Cu.....	2.4	9.98
Hg.....	1.2	9.55	Ag.....	2.4	9.98
Cd.....	1.2	9.56		Br <sub>2</sub> in KBr	
			Hg.....	3.3	12.27

\* These and further results in original seem to show that these five metals dissolve in I<sub>2</sub> + KI with the same velocity, expressed in equivalents of metal dissolving.



## 8. MAGNESIUM AND ZINC IN AQUEOUS ACIDS

Rotary stirring, 300 r.p.m.; value of  $S$  in doubt, but apparently  $0.22 \text{ cm}^2$  in all experiments;  $25^\circ\text{C}$ .  $K_a$  = Ionization constant (<sup>22</sup>).

Solution, initial concn. in mole/l	$K \times S,$ $\text{cm}^3/\text{min}^*$	$K_a$
<b>Mg</b>		
HCl, 0.1.....	1.12	
HCl, 0.1 + MgCl <sub>2</sub> , 0.0671.....	1.25	
HCl, 0.1 + MgCl <sub>2</sub> , 0.1341.....	1.31	
HAc (Acetic acid), 0.1.....	0.405	
HAc, 0.1 + Mg(Ac) <sub>2</sub> , 0.1.....	0.366	
HAc, 0.1 + Mg(Ac) <sub>2</sub> , 0.2.....	0.326	
HAc, 0.1 + MgSO <sub>4</sub> , 0.2.....	0.416	
HAc, 0.1 + Na <sub>2</sub> SO <sub>4</sub> , 0.2.....	0.454	
HAc, 0.1 + NaAc, 0.2.....	0.441	
H <sub>2</sub> SO <sub>4</sub> , 0.05.....	1.15	
H <sub>2</sub> SO <sub>4</sub> , 0.05 + KCl, 0.1341.....	1.43	
H <sub>2</sub> SO <sub>4</sub> , 0.05 + KBr, 0.1341.....	1.64	
H <sub>2</sub> SO <sub>4</sub> , 0.05 + KI, 0.1341.....	1.48	
HCl, 0.02.....	1.27	
2,5-Dihydroxybenzoic acid.....	0.774	$108 \times 10^{-5}$
2,4-Dihydroxybenzoic acid.....	0.518	$52 \times 10^{-5}$
Tricarballic acid, 0.02.....	0.493	$22 \times 10^{-5}$
Acetic acid (HAc), 0.02.....	0.449	$1.8 \times 10^{-5}$

Zn		
HCl, 0.1.....	0.133	After period of induction

## 9. METALS IN AQUEOUS HYDROCHLORIC ACID

After period of induction or adequate pretreatment with acid. (a) A plate of the metal with one surface exposed, attached eccentrically to stirrer stem, acts as blade of stirrer. Radius of path not given; 100 r.p.m.; 25°C. (b) Same apparatus and temp. Stirrer stationary.

(a)	Metal	Solution, initial conc. in mole/l		K, cm/min	Lit.
		HCl	Salt		
	Al*	0.5	AlCl <sub>3</sub> , 0.33 AlCl <sub>3</sub> , 1.0 KCl, 1.0	0.0025	(8)
		1.0		0.0037	
		1.5		0.026	
		2.0		0.057	
		3.0		0.088	
		4.0		0.123	
		1.0		0.044	
		2.0		0.064	
	Zn† Mg‡	1.0		0.0078	(7) (5)
		2.0		0.10	
		0.125		0.41	
(b)	Mg§	0.0625		0.20	(6)
		0.125		0.27	
		0.25		0.32	

Ferric chloride, $24.6 \pm 0.1^\circ\text{C}$		
HCl, mole/l	0.1	0.5
Cd.....	4.19	4.17
Fe.....	4.14	4.35
Cu.....	3.44	4.20

Chromic acid* (added as CrO <sub>3</sub> ), 25 ± 0.1°C			
H <sub>2</sub> SO <sub>4</sub> , mole/l	0.25	1.25	5.0
Cd.....	7.02	5.32	2.67
Ni.....	irregular		2.67
Sn.....			2.74
Cu.....	6.95	5.34	2.72
Ag.....	4.28		1.22

6. METALS IN AQUEOUS FERRIC SULFATE (9)  
 $18 \pm 0.1^\circ\text{C}$ ; no stirring; dissolving surface vertical;  $S = 22.5 \text{ cm}^2$

Metal	Cu	Fe	Cd	Sn
$K$ , cm/min.....	0.0142	0.0138	0.0144	0.0137

## 7. COPPER IN AQUEOUS FERRIC CHLORIDE AND CUPRIC CHLORIDE

Salt	No. of exps.	Initial concentration, mole/l	Mean, $K$ , cm/min
FeCl <sub>3</sub> , alone.....	3	(0.186) (0.191) (0.290)	0.205
CuCl <sub>2</sub> , alone.....	2	(0.166) (0.195)	0.205
FeCl <sub>3</sub> + CuCl <sub>2</sub> .....	4	Various	0.204
		Mean of the 9 exps.	0.2044

10. PbS, ZnS AND RELATED MINERALS IN DILUTE SULFURIC ACID  
Material, screened fragments of uniform size. No stirring. Velocities were proportional to concentration of acid between 0.0125 and 1.25%  $H_2SO_4$ . The relative values of the velocity constant tabulated below were the same at all temperatures between 0 and 50° (15, 16).

Mineral	Locality	$K_{arb.}$
Galena (PbS, about 98%)	Clausthal	1.00
Sphalerite (ZnS, about 99%)	Spain	3.2
Sphalerite (Pb, 11.4%; Fe, 3.6%)	Clausthal	6.3



## 10.—(Continued)

Mineral	Locality	$K_{arb.}$
Sphalerite (Pb, 14.9%; Fe, 3.5%; SiO <sub>2</sub> , 11%)	Bensberg	11.1
Christophite (ferriferous ZnS; Fe, 16%; SiO <sub>2</sub> , 19%)	Breitenbrunn	14.0

## 11. MINERAL CARBONATES IN ACIDS

Material, except in cases of malachite and marble, large crystals. Single exposed surface vertical. Stirring by gas evolved only; 15°C (19, 20).

Mineral	Acid	$K_{arb.}$	Remarks
Iceland spar (CaCO <sub>3</sub> )	HCl, HNO <sub>3</sub> or HI	1.00	Cleavage face. Velocity with HBr ca. 40% higher
Aragonite (CaCO <sub>3</sub> )	HCl or HNO <sub>3</sub>	0.48	Face (010)
Dolomite (CaCO <sub>3</sub> .MgCO <sub>3</sub> )	HCl or HNO <sub>3</sub>	0.025	Face not specified
Witherite (BaCO <sub>3</sub> )	HCl or HNO <sub>3</sub>	1.28	Face not specified
Smithsonite (ZnCO <sub>3</sub> )	HCl or HNO <sub>3</sub>	0.087	Face not specified
Cerussite (PbCO <sub>3</sub> )	HNO <sub>3</sub>	0.76	Face (010)
Azurite [2CuCO <sub>3</sub> .Cu(OH) <sub>2</sub> ]	HCl or HNO <sub>3</sub>	0.33	Face not specified
Malachite [CuCO <sub>3</sub> .Cu(OH) <sub>2</sub> ]	HCl or HNO <sub>3</sub>	0.23	Massive
Marble (CaCO <sub>3</sub> )	HCl or HNO <sub>3</sub>	1.7	Massive

## 12. COPPER IN AQUEOUS AMMONIA

Reaction autocatalytic, accelerated by dissolved copper.  $K = \frac{v}{S(C + \alpha)} \frac{dC}{dt} = \frac{v}{S(t_2 - t_1)} \ln \frac{C_2 + \alpha}{C_1 + \alpha}$  in which  $C$  = concentration of dissolved copper.  $\alpha = \frac{K_0}{K}$ ,  $K_0 = \left( \frac{v}{S} \frac{dC}{dt} \right)_{C=0}$ , the initial velocity. For a given concentration of dissolved oxygen  $K_0$  and  $\alpha$  are constants.  $K_0$  is approximately proportional to the square root of the oxygen concentration;  $K$  is practically independent of it. The validity of this equation ends abruptly with the formation of an oxide coating on the metal, due to accumulation of OH<sup>-</sup> ions produced by the reaction. This stage is deferred by a higher concentration of ammonia, and also by ammonium salts.

Mean values of  $K$  for various constant concentrations of ammonia in solutions kept saturated with air. Two copper plates 1.5 × 1.3 cm describe in liquid a circular path 2 cm in radius, 1120 r.p.m.;  $S = 7.6$  to  $8.6$  cm<sup>2</sup>; 24.8°C (32).

$$K_0 = 13.6 \times 10^{-4}$$

NH <sub>3</sub> , mole/l	NH <sub>4</sub> salt, mole/l	$\alpha = 0.0020$ $K, ^\circ \text{cm/min}$
1.047	0	0.640
1.921	0	0.703
3.963	0	0.653
1.047	(NH <sub>4</sub> ) <sub>2</sub> SO <sub>4</sub> , 0.01	0.710
1.088	(NH <sub>4</sub> ) <sub>2</sub> SO <sub>4</sub> , 0.05	0.680
1.080	(NH <sub>4</sub> ) <sub>2</sub> SO <sub>4</sub> , 0.1	0.671
1.080	NH <sub>4</sub> NO <sub>3</sub> , 0.1	0.681
1.080	NH <sub>4</sub> Cl, 0.1	0.691
		Mean 0.679

\* The results show that within these limits  $K$  is independent of the concentration of free ammonia and of ammonium salts.

## 13. SILVER IN AQUEOUS POTASSIUM CYANIDE

For constant concentration of dissolved oxygen  $K = \frac{v}{St} \left[ m(C_0 - C) + \log_{10} \frac{C_0}{C} \right]$  in which  $C$  = concn. of KCN,  $C_0$  = initial concn.,  $m = \text{a constant} = 0.4343 \frac{k_2}{k_1}$  ( $k_2$  = velocity constant of the diffu-

sion of cyanide.  $k_1$  = velocity constant of the chemical reaction at interface). The validity of this equation is ultimately disturbed by OH<sup>-</sup> ions produced by the reaction itself, and the sooner the smaller the value of  $C_0$ .

Mean values of  $K$  and  $m$  for various initial concentrations of KCN for solutions kept saturated with air.\* Stirring like last; 600 r.p.m.; two silver plates 1.5 × 1.2 cm;  $S = 7.3$  to  $8.7$  cm<sup>2</sup>, 25°C (33).

$C_0$ , mole/l	$m$	$K$ , cm/min	$C_0$ , mole/l	$m$	$K$ , cm/min
0.1480	135	0.226	0.0042	140	0.231
0.0632	140	0.230	0.0022	150	0.217
0.0316	145	0.231	0.0011	150	0.209
0.0158	155	0.222			
0.0079	140	0.225		Mean 144.4	0.224

\* In solutions saturated with pure oxygen the velocity of dissolving,  $\frac{dC_{Ag}}{dt}$  was 2.5 times larger, indicating approximate proportionality with  $[O_2]^{1/2}$ .  $K$  was also increased but in a somewhat smaller ratio.

## 14. ZINC IN HCL DISSOLVED IN ALCOHOLS AND IN ACETONE

A thin rod of zinc mechanically raised and lowered in liquid 72 times per minute.  $S = 2.78$  cm<sup>2</sup>; organic solvents anhydrous, and contained initially 0.5 mole/l of HCl; presence of a small amount of H<sub>2</sub>O in CH<sub>3</sub>OH, C<sub>2</sub>H<sub>5</sub>OH and (CH<sub>3</sub>)<sub>2</sub>CO lowered velocity; 20°C (34).

HCl in	Methyl alc.	Ethyl alc.	Amyl alc.	Acetone	H <sub>2</sub> O
$K$ , cm/min	0.37	0.17	<0.01	0.42	0.14

## TEMPERATURE COEFFICIENTS

M designates mechanical stirring; G, stirring by gas evolved by reaction; O, no stirring

Reaction and stirring	Comparable velocities at two temperatures	$\frac{K_{t+10^\circ}}{K_t}$	Lit.
Benzoic acid in H <sub>2</sub> O, M	(1.587) <sub>1.5</sub> (2.851) <sub>17.5</sub> (4.524) <sub>31</sub> (5.756) <sub>40</sub>	(2.851) <sub>17.5</sub> (4.524) <sub>31</sub> (5.756) <sub>40</sub> (9.946) <sub>60</sub>	1.442 1.408 1.307 1.314 (31)
Cd in I <sub>2</sub> + KI, M	(3.72) <sub>0</sub> (5.87) <sub>15</sub> (7.62) <sub>25</sub> (9.55) <sub>35</sub> (11.81) <sub>45</sub> (14.26) <sub>55</sub>	(5.87) <sub>15</sub> (7.62) <sub>25</sub> (9.55) <sub>35</sub> (11.81) <sub>45</sub> (14.26) <sub>55</sub> (16.93) <sub>65</sub>	1.356 1.298 1.253 1.237 1.207 1.187 (25)
K <sub>2</sub> SO <sub>4</sub> in H <sub>2</sub> O, M	(0.027) <sub>4.8</sub> (0.071) <sub>30.1</sub>	(0.071) <sub>30.1</sub> (0.166) <sub>68.9</sub>	1.47 1.25 (12)
K <sub>2</sub> Cr <sub>2</sub> O <sub>7</sub> in H <sub>2</sub> O, M	(0.026) <sub>4.8</sub>	(0.073) <sub>35.3</sub>	1.40
NaClO <sub>3</sub> in H <sub>2</sub> O, M	(0.043) <sub>4.8</sub> (0.183) <sub>35.1</sub>	(0.083) <sub>30.1</sub> (0.261) <sub>44.7</sub>	1.30 1.45
Benzoic acid in H <sub>2</sub> O, M	(2.30) <sub>20</sub>	(3.35) <sub>30</sub>	1.5 (4)
Mg(OH) <sub>2</sub> in benzoic acid, M	(1.55) <sub>20</sub>	(2.35) <sub>30</sub>	1.5
Mg(OH) <sub>2</sub> in HCl, M	(8.1) <sub>20</sub>	(12.2) <sub>30</sub>	1.5
Cu in FeCl <sub>3</sub> or CuCl <sub>2</sub> , M	(0.1508) <sub>15</sub>	(0.2044) <sub>25</sub>	1.36 (2)
Cu in Fe <sub>2</sub> (SO <sub>4</sub> ) <sub>3</sub> , O	(0.031) <sub>0</sub> (0.045) <sub>11</sub> (0.054) <sub>18</sub>	(0.045) <sub>11</sub> (0.054) <sub>18</sub> (0.070) <sub>25</sub>	1.40 1.30 1.45 (9)
Fe in Fe <sub>2</sub> (SO <sub>4</sub> ) <sub>3</sub> , O	(0.055) <sub>18</sub> (0.037) <sub>0</sub>	(0.074) <sub>25</sub> (0.048) <sub>11</sub>	1.53 1.27
Cd in Fe <sub>2</sub> (SO <sub>4</sub> ) <sub>3</sub> , O	(0.048) <sub>11</sub> (0.062) <sub>18</sub>	(0.062) <sub>18</sub> (0.076) <sub>25</sub>	1.44 1.34
Sn in Fe <sub>2</sub> (SO <sub>4</sub> ) <sub>3</sub> , O	(0.030) <sub>0</sub> (0.050) <sub>18</sub>	(0.050) <sub>18</sub> (0.062) <sub>25</sub>	1.33 1.36
Cu in K <sub>2</sub> Cr <sub>2</sub> O <sub>7</sub> + H <sub>2</sub> SO <sub>4</sub> , M	(8.15) <sub>21</sub> (10.38) <sub>31</sub>	(10.38) <sub>31</sub> (13.03) <sub>41</sub>	1.27* 1.26 (29)
Cu in NH <sub>4</sub> OH (air-satd.), M	(2.094) <sub>19.8</sub> (2.263) <sub>24.8</sub>	(2.263) <sub>24.8</sub> (2.588) <sub>34.8</sub>	1.17 1.14 (32)



## TEMPERATURE COEFFICIENTS.—(Continued)

Reaction and stirring	Comparable velocities at two temperatures	$\frac{K_{t+10}}{K_t}$	Lit.
Ag in KCN (air-satd.), M	(2.51) <sub>15</sub> (2.82) <sub>25</sub> (2.82) <sub>25</sub> (3.26) <sub>35</sub> (3.26) <sub>35</sub> (3.84) <sub>45</sub>	1.13 1.16 1.18	(33)
Mg in HCl, G	(2054) <sub>0</sub> (3059) <sub>25</sub> (3059) <sub>25</sub> (5564) <sub>50</sub> (1.00) <sub>50</sub> (1.51) <sub>75</sub>	1.17† 1.27 1.2†	(6) (3)
Al in HCl (2N), M	(55) <sub>0</sub> (1396) <sub>45</sub>	2.05	(8)
Al in HCl (3N), M	(248) <sub>0</sub> (982) <sub>25</sub>	1.73	
Fe in HCl, G	(2.5) <sub>50</sub> (5.8) <sub>61.4</sub> (5.8) <sub>61.4</sub> (19) <sub>75.4</sub>	2.1 2.0	(18)
Fe in H <sub>2</sub> SO <sub>4</sub> , G	(1.83) <sub>2.3</sub> (11.5) <sub>28.7</sub> (11.5) <sub>28.7</sub> (26.2) <sub>45</sub> (26.2) <sub>45</sub> (63.1) <sub>55.5</sub>	2.0 1.7 1.9	(10)
Iceland spar in HCl, G	(0.044) <sub>0</sub> (0.095) <sub>15</sub> (0.095) <sub>15</sub> (0.251) <sub>35</sub> (0.251) <sub>35</sub> (0.565) <sub>55</sub>	1.67 1.62 1.50	(21)
Witherite in HCl, G	(0.122) <sub>15</sub> (0.406) <sub>35</sub>	1.8	(20)
Azurite in HCl, G	(0.031) <sub>15</sub> (0.062) <sub>35</sub>	1.4	
Dolomite in HCl, G	(0.0024) <sub>15</sub> (0.0046) <sub>35</sub>	1.38	
Smithsonite in HCl, G	(0.0083) <sub>15</sub> (0.0142) <sub>35</sub>	1.31	
Malachite in HCl, G	(0.022) <sub>15</sub> (0.037) <sub>35</sub>	1.30	
PbS, ZnS (minerals) in dilute H <sub>2</sub> SO <sub>4</sub> , O	Range 0 to 80° (8 temps.), coefficient constant	1.54	(15)
Cu in benzaldehyde dissolved in toluene, 10% by Vol. O	(52.8) <sub>40</sub> (72.2) <sub>50</sub> (72.2) <sub>50</sub> (106) <sub>60</sub> (106) <sub>60</sub> (153) <sub>70</sub> (153) <sub>70</sub> (220) <sub>80</sub> (220) <sub>80</sub> (320) <sub>90</sub> (320) <sub>90</sub> (455) <sub>100</sub>	1.36 1.46 1.44 1.43 1.45 1.42	(17)

\* Two other determinations at different concentrations but same temperature range gave 1.29 and 1.30, respectively.

† Practically the same value was obtained also in mechanically stirred solutions.

## RELATIVE VELOCITIES FOR DIFFERENT CRYSTAL FACES

In the case of simple (reversible) solution in a solvent a difference in the observed velocities of dissolving of two faces of the same crystal may be partly or wholly due to a difference in the solubilities ( $C_s$ ) of the two faces, rather than in their velocity constants  $K$ . In some cases the evidence decidedly favors this explanation, notably when the velocities for the two faces differ appreciably only when the solution is nearly saturated.

## SODIUM CHLORIDE IN WATER AND IN VARIOUS SOLUTIONS

Dissolving face vertical. No stirring. 25°C (14). The table summarizes results for other faces compared with results for cube. Owing to influence of convection currents,  $K$  for cube increased linearly with ( $C_s - C$ ). A face other than the cube gave a different value of  $K$  and a different rate of increase if  $C_s$  for cube was used in the calculations, but complete agreement was obtained by assuming  $C_s$  for the second face to differ by the percentage amount,  $\Delta$ . Differences were appreciable only in solutions very nearly saturated, and disappeared entirely if saturation was 90% or less. The author concludes that  $K$  has the same value within error of experiment for all faces of NaCl, and that  $\Delta$  represents actual percentage differences in the solubility of the given face from that of the cube.

	Various faces in pure NaCl solutions, $\Delta\%$	With formamide, 150 g/l, $\Delta\%$
Octahedron	+0.04	-0.4
Tetrahedron (310)	$\pm 0.00$	$\pm 0.0$

## SODIUM CHLORIDE.—(Continued)

	Various faces in pure NaCl solutions $\Delta\%$	With formamide, 150 g/l, $\Delta\%$
Tetrahedron (320)	-0.18	
Dodecahedron	-0.18	-0.4
Trisectahedron (221)	$\pm 0.00$	-0.3
Hexoctahedron (321)	-0.18	-0.2
Trapezohedron (211)	-0.18	-0.2

## Octahedron in NaCl solutions containing

Urea		Formamide		KNO <sub>3</sub>	
g/l	$\Delta\%$	g/l	$\Delta\%$	g/l	$\Delta\%$
0	$\pm 0.04$	23	$\pm 0.0$	40	$\pm 0.0$
50	$\pm 0.00$	53	$\pm 0.0$	80	$\pm 0.0$
96	-0.10	80	-0.2	120	+0.1
130	-0.12	110	-0.3	160	+0.1
180	-0.17	150	-0.4	200	$\pm 0.0$
230	-0.34	188	-0.4		
280	-0.42				

GYPSUM (CaSO<sub>4</sub>·2H<sub>2</sub>O) IN WATER

$C_s = 2.094$  g/l (anhyd. salt).  $C$  at all times  $< 0.16C_s$ ; rotary stirring; relative velocities for surfaces cut parallel to pinacoid (010), prism (110) and pyramid (111); 25° (23).

$$V_{010}:V_{110}:V_{111} = 1.00:1.76:1.88$$

Wagner (30) finds at 25°  $V_{010}:V_{111} = 1.00:156$ .

CuSO<sub>4</sub>·5H<sub>2</sub>O IN WATER

$C_s = 228.0$  g/l (anhydrous salt);  $C$  at start =  $0.9175C_s$ ; method like last; 24.9° (24).

$$V_{110}:V_{111} = 1.00:1.27$$

## TARTARIC ACID AND SALTS IN WATER

Relative velocities. Two unlike faces acted upon simultaneously.

Exposed surfaces vertical; no stirring; ca. 20° (11)

Tartaric acid in water	(100)	(101)	(110)	(110)	(101)	(011)	(001)
$C = 875$ g/l	1.00	1.29	1.49	1.55	1.63	1.68	1.76
CuSO <sub>4</sub> ·5H <sub>2</sub> O in water	(100)	(110)	(111)	(010)	(110)		
$C = 168$ g/l (anhyd. salt)	1.00	1.37	1.28	1.18	1.12		
K <sub>4</sub> Fe(CN) <sub>6</sub> ·3H <sub>2</sub> O in water	(010)	(110)	(011)				
$C = 389$ g/l (anhyd. salt)	1.00	1.79	1.86				

NaNO<sub>3</sub> IN WATER

$C = 485.5$  g/l; no stirring; 25° (13)

Rhombohedral (1010)	Rhombohedral (1210)	Base (0001)
$V = 11.8$	10.7	10.8 mg/cm <sup>2</sup> min <sup>-1</sup>

MgSO<sub>4</sub>·7H<sub>2</sub>O IN WATER

$C = 331$  g/l (anhyd. salt); no stirring (13)

Base (001)	Pinacoid (010)	Prism (110)	Sphenoid (111)
$V = 3.7$	3.5	3.5	3.7 mg/cm <sup>2</sup> min <sup>-1</sup>

## QUARTZ IN HYDROFLUORIC ACID

Sol. I: HF = 97.18 g/l; Sol. II: HF = 201.7 g/l; no stirring (13)

	Base (0001)	Prism (1120)	Prism (1010)	Rhombohedral (1011)
(I) $V =$	7.2	1.15	1.17	0.97 mg/cm <sup>2</sup> day <sup>-1</sup>
(II) $V =$	18.76	4.37	4.41	3.7 mg/cm <sup>2</sup> day <sup>-1</sup>

## ICELAND SPAR IN HCL

Single exposed surface vertical. Stirring by gas evolved only. 15° (21). For surfaces cut, 1, parallel to principal axis; 2, parallel to cleavage plane; and 3, perpendicular to axis.

$$V_1:V_2:V_3 = 1.00:1.05:1.14$$



$\alpha$ -CHLORODINITROBENZENE IN ETHER (1)

Prism (110) was compared with pinacoid (001). When the same value of  $C_s$  was used in the calculations for both faces the ratio  $K_{(110)}:K_{(001)}$  varied with the concentration, reaching 0.4 in nearly saturated solution but approaching unity at slightly lower concentration. The author concludes that  $K_{(110)} = K_{(001)}$  and that observed differences are due entirely to the fact that prism face is less soluble than the pinacoid. 15.1° and 19.8°; mechanical stirring.

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(For a key to the periodicals see end of volume)

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## VELOCITY OF CRYSTALLIZATION

H. C. BURGER

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## MATIÈRES

Formation of crystal nuclei. Formation des noyaux cristallins.  
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## FORMATION OF CRYSTAL NUCLEI

If extraneous influences are eliminated, the number,  $N$ , of nuclei which are formed at a given temperature should be proportional to the volume of the liquid and to the time. This number is a characteristic temperature function of the liquid. Transition in the crystal state from one form to another can occur spontaneously in a similar manner.

The measurements of the number of nuclei are however not very accurate, and the values given below represent, therefore, only order of magnitude. The first temperature given is the melting point.  $N$  is given in  $\text{cm}^{-3} \text{sec}^{-1}$ .

## FORMATION DES NOYAUX CRISTALLINS

Si l'on élimine les influences extérieures, le nombre,  $N$ , de noyaux qui sont formés à une température donnée doit être proportionnel au volume du liquide et au temps. Ce nombre est pour un liquide une fonction caractéristique de la température. La transition à l'état cristallin d'une forme dans une autre peut se produire spontanément d'une manière analogue.

Les mesures du nombre de noyaux ne sont cependant pas très précises et les valeurs données ci-dessous ne représentent par conséquent que l'ordre de grandeur. La première température donnée est le point de fusion.  $N$  est exprimé en  $\text{cm}^{-3} \text{sec}^{-1}$ .

## Diopside (Zermatt) (44)

$t, ^\circ\text{C}$	1310	1260	1200	1175
$N$	0	60	150	180

## Melilite (Alnö, Sweden) (44)

$t, ^\circ\text{C}$	1180	1130	1100	1080	1060
$N$	0	120	300	430	500

## Spinel (Amity, N. Y.) (44)

$t, ^\circ\text{C}$	1360	1225	1210	1200	1185	1175
$N$	0	60	180	270	420	570

## Hedenbergite (Nordmarken) (44)

$t, ^\circ\text{C}$	1160	1120	1100	1080
$N$	0	70	180	250

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## BILDUNG VON KRISTALLKEIME

Wenn äussere Einflüsse eliminiert sind, sollte die Zahl,  $N$ , der bei gegebener Temperatur gebildeten Keime, dem Volum der Flüssigkeit und der Zeit proportional sein. Diese Zahl ist eine für die Flüssigkeit charakteristische Temperaturfunktion. In ähnlicher Weise können im kristallisierten Zustande spontan Übergänge von der einen Form in die andere stattfinden.

Die Messungen der Keimzahl sind aber nicht sehr genau, und die folgenden Werte geben deshalb nur die Grössenordnung an.  $N$  ist in  $\text{cm}^{-3} \text{sec}^{-1}$  gegeben.

## FORMAZIONE DEI GERMI CRISTALLINI

Quando siano eliminate influenze esterne, il numero,  $N$ , di germi che si formano ad una data temperatura, deve essere proporzionale al volume di liquido ed al tempo. Questo numero è una funzione della temperatura caratteristica per il liquido. In maniera simile possono verificarsi trasformazioni (allo stato solido) di una forma cristallina nell'altra.

Le misure del numero di germi non sono però molto esatte, ed i valori seguenti danno perciò solo un'idea dell'ordine di grandezza. La prima temperatura data è il punto di fusione.  $N$  è dato in  $\text{cm}^{-3} \text{sec}^{-1}$ .

## Aegirite (Lange Sundfjord) (44)

$t, ^\circ\text{C}$	1020	1000	975	950
$N$	0	80	130	160

3, 4-Dinitrobromobenzene, 3, 4-( $\text{O}_2\text{N}$ )<sub>2</sub> $\text{C}_6\text{H}_3\text{Br}$ .— $N$  is the number of nuclei of the stable form (M. P. = 59.5°) in the metastable crystal phase (M. P. = 34.8°) (45).

$^\circ\text{C}$	10	$\pm 0$	-10	-20	-30	-40	-50	-60	-70	-80
$N$	0.01	0.1	0.3	1	1	2	4	2	0.3	0.3

Betol ( $\beta$ -Naphthyl Salicylate)  $\text{OHC}_6\text{H}_4\text{CO}_2\text{C}_{10}\text{H}_7$ .— $N$  is a maximum at  $15 \pm 5^\circ$  and equals 0.7 to 2 (45).

Piperine,  $\text{C}_{17}\text{H}_{19}\text{NO}_3$ .— $N$  is a maximum at  $40 \pm 5^\circ$  and equals 0.2 to 10 (45); cf. (54).



## CRYSTAL GROWTH

The linear crystallization velocity at the crystal-liquid boundary is a function of its temperature (9, 10) which, however, is seldom measured (10, 53), the temperature of the surrounding bath only, being known. The maximum linear crystallization velocity (K. G.) of the liquid or transition velocity (U. G.) of one crystal phase to another is a characteristic property of the substance, which, however, is very sensitive to impurities, so that the values recorded below may be 5-10% in error from this cause, in cases where another precision is not indicated.

Maximum linear crystallization (K. G.) and transition (U. G.) velocities. The unit is millicentimeters ( $10^{-3}$  cm) per sec; M. P. = melting point, °C; (s) = stable form; (m) = metastable form.

## ACCROISSEMENT DU CRISTAL

La vitesse de cristallisation linéaire dans la zone cristal liquide est une fonction de sa température (9, 10) qui est cependant rarement mesurée (10, 53). Dans la plupart des cas on ne connaît que la température du bain environnant. La vitesse maximum de cristallisation linéaire (K. G.) du liquide, ou la vitesse de transition (U. G.) d'une phase cristalline en une autre, est une propriété caractéristique de la substance qui est cependant très sensible aux impuretés. Les valeurs données ci-dessous peuvent donc être entachées d'une erreur de 5 à 10% lorsque la limite de l'erreur n'est pas exprimée.

Vitesse maximum de cristallisation linéaire (K. G.) et vitesse de transition (U. G.). L'unité est le millicentimètre ( $10^{-3}$  cm) par sec; M. P. = point de fusion, °C; (s) = forme stable; (m) = forme metastable.

Formula	Name	K. G. or U. G.	Lit.
H <sub>3</sub> PO <sub>4</sub>	Orthophosphoric acid, M. P. 36.6°	1.8 ± 0.2	(5)
Ca(NO <sub>3</sub> ) <sub>2</sub> ·4H <sub>2</sub> O	Calcium nitrate, 4-hydrate	22.7 ± 0.3	(20, 22, 28)
Cd(NO <sub>3</sub> ) <sub>2</sub> ·4H <sub>2</sub> O	Cadmium nitrate, 4-hydrate	50	(22)
Na <sub>2</sub> S <sub>2</sub> O <sub>3</sub> ·5H <sub>2</sub> O	Sodium thiosulfate, 5-hydrate (s)	195	(37)
Na <sub>2</sub> S <sub>2</sub> O <sub>3</sub> ·5H <sub>2</sub> O	Sodium thiosulfate, 5-hydrate (m)	185	(37)
Na <sub>2</sub> S <sub>2</sub> O <sub>3</sub> ·5H <sub>2</sub> O	m → s, U. G. =	83	(37)
C <sub>2</sub> H <sub>3</sub> ClO <sub>2</sub>	Chloroacetic acid:		
	(M. P.) <sub>I</sub> = 61.3°; (M. P.) <sub>II</sub> = 56.2°;		
	(M. P.) <sub>III</sub> = 50.2°		
	III → II, U. G. =	120	(37)
C <sub>2</sub> H <sub>3</sub> BrO <sub>2</sub>	II → I, U. G. =	95	(37)
	III → I, U. G. =	410	(37)
	α, β-Dibromopropionic acid:		
C <sub>2</sub> H <sub>3</sub> BrO <sub>2</sub>	s, M. P. = 64°, K. G. =	5.8	(37)
	m, K. G. =	7.2	(37)
	m → s, U. G. =	1.4	(37)
C <sub>2</sub> H <sub>5</sub> N <sub>2</sub> O	Ethylurea, M. P. = 95°	145	(37)
C <sub>4</sub> H <sub>10</sub> O <sub>4</sub>	Erythritol (s)	45	(4, 37)
C <sub>6</sub> H <sub>3</sub> ClN <sub>2</sub> O <sub>4</sub>	3, 4-Dinitrochlorobenzene, M. P. 50°	6.5	(37)
C <sub>6</sub> H <sub>3</sub> N <sub>2</sub> O <sub>7</sub>	Pieric acid	1430	(4)
C <sub>6</sub> H <sub>5</sub> FNO <sub>2</sub>	m-Fluoronitrobenzene	25	(22)
C <sub>6</sub> H <sub>5</sub> ClNO <sub>2</sub>	m-Chloronitrobenzene	1500	(22, 48)
C <sub>6</sub> H <sub>5</sub> BrNO <sub>2</sub>	m-Bromonitrobenzene	1150	(3, 22)
C <sub>6</sub> H <sub>5</sub> INO <sub>2</sub>	m-Iodonitrobenzene	200	(22)
C <sub>6</sub> H <sub>4</sub> O <sub>2</sub>	Resorcinol I, M. P. = 110°, K. G. =	700	(27)
	Resorcinol II, M. P. = 108, K. G. =	450	(27)
	I → II, U. G. =	0.70 ± 0.07	(27)
C <sub>6</sub> H <sub>11</sub> NO <sub>2</sub>	Ethyl β-aminoacrylate (s)	58	(37)
C <sub>7</sub> H <sub>7</sub> NO	Formanilide	1.75	(13)
C <sub>7</sub> H <sub>5</sub> O <sub>2</sub>	Guaiacol	9.3	(15)
C <sub>7</sub> H <sub>5</sub> O <sub>2</sub>	Phthalide	25	(37)
C <sub>9</sub> H <sub>10</sub> O <sub>2</sub>	Hydrocinnamic acid	470	(15)
C <sub>10</sub> H <sub>9</sub> N	α-Naphthylamine	110	(14)
C <sub>10</sub> H <sub>11</sub> NO <sub>4</sub>	1-Hydroxy-2(p-nitrophenyl)-ethyl methyl ketone	2.5	(5)
C <sub>12</sub> H <sub>10</sub> N <sub>2</sub>	Azobenzene, I, M. P. = 115°; II, M. P. = 128°		
	I → II, U. G. =	530	(37)

## KRISTALLWACHSTUM

Die lineare Kristallisationsgeschwindigkeit an der Grenze Kristall-Flüssigkeit ist eine Funktion deren Temperatur (9, 10), welche aber selten gemessen ist (10, 53). Meistens ist nur die Temperatur des umgebenden Bades bekannt. Die maximale lineare Kristallisationsgeschwindigkeit der Flüssigkeit (K. G.) oder die Umwandlungsgeschwindigkeit (U. G.) der einen Kristallphase in die andere ist eine charakteristische Eigenschaft der Substanz, welche aber sehr empfindlich gegen Verunreinigungen ist. Deshalb können die unten angegebenen Werte mit einem Fehler von 5-10% behaftet sein, wenn keine andere Fehlergrenze genannt wird.

Maximale lineare Kristallisationsgeschwindigkeit (K. G.) und Umwandlungsgeschwindigkeit (U. G.). Die Einheit ist  $10^{-3}$  cm pro sec; M. P. = Schmelzpunkt, °C; (s) = stabile Form; (m) = metastabile Form.

## ACCRESIMENTO DEI CRISTALLI

La velocità lineare di cristallizzazione in corrispondenza della zona di contatto cristallo-liquido è una funzione della temperatura (9, 10) alla quale essa si trova; questa temperatura però raramente è stata misurata direttamente (10, 53). Per lo più si conosce soltanto la temperatura del bagno nel quale il sistema in esame è immerso. La velocità lineare massima di cristallizzazione di un liquido (K. G.) o di trasformazione (U. G.) di una fase cristallina nell'altra è una proprietà caratteristica delle sostanze. Essa risente però molto l'influenza delle impurezze, per modo che i valori sotto riportati possono essere inesatti del 5-10%, quando non siano indicati altri limiti di errore.

Velocità lineare massima di cristallizzazione (K. G.) e velocità di trasformazione (U. G.). L'unità è  $10^{-3}$  cm al secondo; M. P. = punto di fusione, °C; (s) = forma stabile, (m) = forma metastabile.

Formula	Name	K. G. or U. G.	Lit.
C <sub>12</sub> H <sub>11</sub> N	Diphenylamine	190	(14, 15)
C <sub>12</sub> H <sub>14</sub> O <sub>4</sub>	Apiol I, M. P. = 30°	12	(46)
	II, M. P. = 27.5°	24	(46)
C <sub>13</sub> H <sub>10</sub> O	Benzophenone	97 ± 2.5	(14)
C <sub>13</sub> H <sub>10</sub> O <sub>3</sub> *	Salol I, M. P. = 42°	6.5 ± 0.2	(10, 15)
	II, M. P. = 38.8°	1.8	(15)
	III, M. P. = 28.3°	0.45	(15)
C <sub>13</sub> H <sub>11</sub> N	Benzalaniline	26	(22)
C <sub>13</sub> H <sub>13</sub> N	Benzylaniline	2.1	(22)
C <sub>14</sub> H <sub>10</sub> O <sub>2</sub>	Benzil	715	(4)
C <sub>14</sub> H <sub>10</sub> O <sub>3</sub>	Benzoic anhydride	53	(15)
C <sub>17</sub> H <sub>12</sub> O <sub>3</sub>	Betol (β-Naphthyl salicylate)		
	I, M. P. = 95°	1.7	(46)
	III, M. P. = 93°	0.8	(46)
C <sub>18</sub> H <sub>18</sub> N <sub>2</sub> O <sub>4</sub>	Saliperin (Antipyrine salicylate)		
	I, M. P. = 91.8°	3.0	(5)
	II, M. P. = 86.3°	5.0	(5)
C <sub>17</sub> H <sub>19</sub> NO <sub>3</sub> *	Piperine		
C <sub>19</sub> H <sub>16</sub>	Triphenylmethane	33 ± 3	(37)
C <sub>19</sub> H <sub>17</sub> N <sub>3</sub>	Triphenylguanidine,		
	I, M. P. = 139°	21	(27)
	II, M. P. = 144.2°	6.4	(27)
	I → II, U. G. =	1.5	(27)
C <sub>27</sub> H <sub>44</sub> O <sub>8</sub>	Tristearin, M. P. = 71°	2.8	(27)

\* For effect of electric and magnetic fields on undercooled compound, v. (54).

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(For a key to the periodicals see end of volume)

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## INTERDIFFUSION OF GASES AND VAPORS

W. P. BOYNTON AND W. H. BRATTAIN

By the coefficient of diffusion of one gas or vapor into another is meant the quantity  $D$  occurring in the equation  $\frac{\delta p_1}{\delta t} = \frac{\delta}{\delta x} \left( D \frac{\delta p_1}{\delta x} \right)$ ;  $t$  = time,  $p_1$  = partial pressure of the diffusing gas, and  $x$  = a length in the direction of the diffusion (14, 15, 22, 24). As  $D$  varies only slightly with  $p_1$ , a good first approximation is  $\frac{\delta p_1}{\delta t} = D \frac{\delta^2 p_1}{\delta x^2}$ . For a given pair of gases (A, B), the value of  $D$  for diffusion of A into B is the same as that for B into A; also  $D = D_0 \left( \frac{T}{T_0} \right)^m \frac{p_0}{p}$ , where  $D_0$  = the value of  $D$  at  $T_0$  ( $=273^\circ\text{K}$ ) and  $p_0$  ( $=1$  atm.),  $D$  is its value at absolute temperature  $T$  and pressure  $p$ , and  $m$  is a constant which theoretically lies between 1.5 and 2.0, and practically may be taken either as 1.75 or as 2.00, depending upon the gases (9, 10, 14, 15). For methods of measurement, see (13, 17, 22). A temperature gradient in a mixture of two gases produces a diffusion of the more massive molecules towards the region of lower temperature (1, 2, 3, 4, 5). For separation of gases by diffusion through porous septa, see (7, 20); for diffusion through metals, see p. 77; through glass, rubber, and other solids, see p. 76. For diffusion of radioactive gases, see Vol. I, p. 364; of ions in gases, consult the index at the end of the last volume.

### A-B-TABLE

#### DIFFUSION OF GASES INTO GASES

$D = D_0 \left( \frac{T}{T_0} \right)^m \frac{p_0}{p}$ ,  $m = 2.00$  for all cases except those marked \* for which  $m = 1.75$

Gases	$D_0$ , cm/sec	Lit.	Gases	$D_0$ , cm/sec	Lit.
He-Ar.....	0.641*	(12, 19)	H <sub>2</sub> -CO <sub>2</sub> .....	0.550*	(6, 13, 17, 19)
H <sub>2</sub> -O <sub>2</sub> .....	.697*	(6, 11, 13, 17)	H <sub>2</sub> -CH <sub>4</sub> .....	.625*	(17)
O <sub>2</sub> -N <sub>2</sub> .....	.181*	(11, 17)	H <sub>2</sub> -C <sub>2</sub> H <sub>4</sub> .....	.486*	(17)
O <sub>2</sub> -CO.....	.185*	(13, 17)	H <sub>2</sub> -C <sub>2</sub> H <sub>6</sub> .....	.459*	(17)
O <sub>2</sub> -CO <sub>2</sub> .....	.139	(13, 17)	H <sub>2</sub> -air.....	.611*	(17, 21)
O <sub>2</sub> -air.....	.178*	(17)	N <sub>2</sub> O-CO <sub>2</sub> .....	.096	(13, 17)
H <sub>2</sub> -SO <sub>2</sub> .....	.480*	(13)	CO-CO <sub>2</sub> .....	.137*	(13, 17)
H <sub>2</sub> -N <sub>2</sub> .....	.674*	(11)	CO-C <sub>2</sub> H <sub>4</sub> .....	.116*	(17)
H <sub>2</sub> -N <sub>2</sub> O.....	.535*	(17)	CO-C <sub>2</sub> H <sub>6</sub> .....	.153*	(13, 17)
H <sub>2</sub> -CO.....	.651*	(13, 17)	CO-air.....	.138	(13, 17, 23)

#### DIFFUSION OF VAPORS INTO GASES

Vapor	Values of $D_0$ (cm <sup>2</sup> /sec), and of $m$			
	Air	CO <sub>2</sub>	H <sub>2</sub>	Lit.
Hg, mercury.....	0.1124†			(16)
I <sub>2</sub> , iodine.....	0.0654†			(16)
	0.097			(13.1)
H <sub>2</sub> O, water.....	0.220*	0.1387	0.7516*	(9, 10, 11.1, 25)

### C-TABLE.—The C-Arrangement (v. Vol. III, p. viii)

Vapor	Values of $D_0$ (cm <sup>2</sup> /sec), and of $m$			
	Air	CO <sub>2</sub>	H <sub>2</sub>	Lit.
CS <sub>2</sub> , carbon disulfide.....	0.0892	0.063	0.3689	(22, 28)
CH <sub>2</sub> O <sub>2</sub> , formic acid.....	0.1308	0.0874	0.5104	(25)
CH <sub>3</sub> O, methyl alcohol.....	0.1325	0.0879	0.5059*	(25)
C <sub>2</sub> H <sub>3</sub> O <sub>2</sub> , acetic acid.....	0.1064	0.0716	0.4163	(18, 25)
C <sub>2</sub> H <sub>3</sub> O <sub>2</sub> , methyl formate.....	0.0872*			(8)
C <sub>2</sub> H <sub>5</sub> O, ethyl alcohol.....	0.102	0.0685	0.3753	(11.1, 25)
C <sub>3</sub> H <sub>5</sub> O <sub>2</sub> , propionic acid.....	0.0829	0.0588	0.3297	(18, 25)
C <sub>3</sub> H <sub>5</sub> O <sub>2</sub> , ethyl formate.....	0.0840*	0.0573*	0.3368*	(18, 25)
C <sub>3</sub> H <sub>5</sub> O <sub>2</sub> , methyl acetate.....	0.084	0.0567	0.3330	(8, 18, 25)
C <sub>3</sub> H <sub>7</sub> Br, isopropyl bromide.....	0.0902			(18)
C <sub>3</sub> H <sub>7</sub> Br, n-propyl bromide.....	0.085			(18)
C <sub>3</sub> H <sub>7</sub> I, isopropyl iodide.....	0.0802			(18)
C <sub>3</sub> H <sub>7</sub> I, n-propyl iodide.....	0.079			(18)
C <sub>3</sub> H <sub>7</sub> O, isopropyl alcohol.....	0.0818			(18)
C <sub>3</sub> H <sub>7</sub> O, n-propyl alcohol.....	0.085	0.0577	0.3153	(18, 25)
C <sub>4</sub> H <sub>7</sub> O <sub>2</sub> , butyric acid.....	0.067	0.0476	0.264	(18, 25)
C <sub>4</sub> H <sub>7</sub> O <sub>2</sub> , isobutyric acid.....	0.0679	0.0471	0.2713	(18, 25)
C <sub>4</sub> H <sub>7</sub> O <sub>2</sub> , methyl propionate.....	0.0735	0.0528	0.2949	(8, 18, 25)
C <sub>4</sub> H <sub>7</sub> O <sub>2</sub> , propyl formate.....	0.0712	0.0490	0.2810	(18, 25)
C <sub>4</sub> H <sub>7</sub> O <sub>2</sub> , ethyl acetate.....	0.0715	0.0487	0.273	(18, 25)
C <sub>4</sub> H <sub>9</sub> O, n-butyl alcohol.....	0.0703	0.0476	0.2716	(18, 25)
C <sub>4</sub> H <sub>9</sub> O, isobutyl alcohol.....	0.0727	0.0483	0.2771	(18, 25)
C <sub>4</sub> H <sub>9</sub> O, trimethyl carbinol.....	0.087			(18)
C <sub>4</sub> H <sub>9</sub> O, ether.....	0.0778	0.05525	0.2964	(8, 18, 22, 25)
C <sub>4</sub> H <sub>11</sub> N, butylamine.....	0.0821			(18)
C <sub>4</sub> H <sub>11</sub> N, diethylamine.....	0.0884			(18)
C <sub>4</sub> H <sub>11</sub> N, isobutylamine.....	0.0853			(18)
C <sub>5</sub> H <sub>11</sub> O <sub>2</sub> , isovaleric acid.....	0.0544	0.0376	0.2123	(18, 25)
C <sub>5</sub> H <sub>11</sub> O <sub>2</sub> , n-valeric acid.....	0.050			(18)
C <sub>5</sub> H <sub>11</sub> O <sub>2</sub> , ethyl propionate.....	0.0653	0.0450	0.2365	(18, 25)
C <sub>5</sub> H <sub>11</sub> O <sub>2</sub> , isobutyl formate.....	0.0705			(18)
C <sub>5</sub> H <sub>11</sub> O <sub>2</sub> , methyl butyrate.....	0.0633	0.0446	0.242	(18, 25)
C <sub>5</sub> H <sub>11</sub> O <sub>2</sub> , methyl isobutyrate.....	0.0639	0.0451	0.2569	(18, 25)
C <sub>5</sub> H <sub>11</sub> O <sub>2</sub> , propyl acetate.....	0.067			(11.1, 18)
C <sub>5</sub> H <sub>11</sub> O, n-amyl alcohol.....	0.0589	0.0422	0.2340	(25)
C <sub>5</sub> H <sub>11</sub> O, amyl alcohol, fermentation.....	0.0585	0.0419	0.234	(25)
C <sub>6</sub> H <sub>6</sub> , benzene†.....	0.077	0.0528	0.2948*	(11.1, 25)
C <sub>6</sub> H <sub>7</sub> N, aniline.....	0.6095			(13.1)
C <sub>6</sub> H <sub>13</sub> O <sub>2</sub> , caproic acid.....	0.050*			(18)
C <sub>6</sub> H <sub>13</sub> O <sub>2</sub> , isocaproic acid.....	0.0513*			(18)
C <sub>6</sub> H <sub>13</sub> O <sub>2</sub> , amyl formate.....	0.0543*			(18)
C <sub>6</sub> H <sub>13</sub> O <sub>2</sub> , n-butyl acetate.....	0.058†			(18)
C <sub>6</sub> H <sub>13</sub> O <sub>2</sub> , ethyl n-butyrate.....	0.0579	0.0407	0.2236	(18, 25)
C <sub>6</sub> H <sub>13</sub> O <sub>2</sub> , ethyl isobutyrate.....	0.0591	0.0413	0.2289	(18, 25)
C <sub>6</sub> H <sub>13</sub> O <sub>2</sub> , isoamyl formate.....	0.058†			(18)
C <sub>6</sub> H <sub>13</sub> O <sub>2</sub> , isobutyl acetate.....	0.0612*	0.0425*	0.2364*	(18, 25)
C <sub>6</sub> H <sub>13</sub> O <sub>2</sub> , methyl valerate.....	0.0569*			(18)
C <sub>6</sub> H <sub>13</sub> O <sub>2</sub> , propyl propionate.....	0.057	0.0395	0.2115	(18, 25)
C <sub>6</sub> H <sub>14</sub> O, hexyl alcohol.....	0.0499	0.0351	0.1997	(25)
C <sub>7</sub> H <sub>7</sub> Cl, benzyl chloride.....	0.066			(11.1, 18)
C <sub>7</sub> H <sub>7</sub> Cl, m-chlorotoluene.....	0.054*			(18)
C <sub>7</sub> H <sub>7</sub> Cl, o-chlorotoluene.....	0.059			(18)
C <sub>7</sub> H <sub>7</sub> Cl, p-chlorotoluene.....	0.051			(18)
C <sub>7</sub> H <sub>8</sub> , toluene.....	0.0709			(13.1)
C <sub>7</sub> H <sub>11</sub> O <sub>2</sub> , ethyl valerate.....	0.0512	0.0367	0.2052	(18, 25)
C <sub>7</sub> H <sub>11</sub> O <sub>2</sub> , isobutyl propionate.....	0.0529*	0.0366*	0.2029*	(18, 25)
C <sub>7</sub> H <sub>11</sub> O <sub>2</sub> , isopropyl isobutyrate.....	0.059†			(18)
C <sub>7</sub> H <sub>11</sub> O <sub>2</sub> , propyl butyrate.....	0.0530	0.0364	0.2059	(18, 25)
C <sub>7</sub> H <sub>11</sub> O <sub>2</sub> , propyl isobutyrate.....	0.0549	0.0388	0.212	(18, 25)
C <sub>8</sub> H <sub>10</sub> , ethylbenzene.....	0.0658*			(18)
C <sub>8</sub> H <sub>10</sub> , m-xylene.....	0.059*			(18)
C <sub>8</sub> H <sub>10</sub> , o-xylene.....	0.062*			(18)
C <sub>8</sub> H <sub>10</sub> , p-xylene.....	0.056			(18)



C-TABLE.—(Continued)

Vapor	Values of $D_0$ (cm <sup>2</sup> /sec), and of $m$			
	Air	CO <sub>2</sub>	H <sub>2</sub>	Lit.
C <sub>5</sub> H <sub>12</sub> O <sub>2</sub> , amyl propionate.....	0.046	0.0347*	0.1914*	(18, 25)
C <sub>5</sub> H <sub>12</sub> O <sub>2</sub> , isobutyl butyrate.....	0.0468	0.0327	0.1850	(18, 25)
C <sub>5</sub> H <sub>12</sub> O <sub>2</sub> , isobutyl isobutyrate.....	0.0457	0.0364*	0.191	(18, 25)
C <sub>5</sub> H <sub>12</sub> O <sub>2</sub> , propyl valerate.....	0.0466	0.0341	0.1893	(18, 25)
C <sub>8</sub> H <sub>18</sub> , <i>n</i> -octane.....	0.0505			(13.1)
C <sub>9</sub> H <sub>12</sub> , isopropylbenzene.....	0.0489			(18)
C <sub>9</sub> H <sub>12</sub> , mesitylene.....	0.056			(18)
C <sub>9</sub> H <sub>12</sub> , <i>n</i> -propylbenzene.....	0.0481			(18)
C <sub>5</sub> H <sub>12</sub> O <sub>2</sub> , amyl butyrate.....	0.040			(18)
C <sub>5</sub> H <sub>12</sub> O <sub>2</sub> , amyl isobutyrate.....	0.0419	0.9307	0.171	(18, 25)
C <sub>5</sub> H <sub>12</sub> O <sub>2</sub> , isobutyl valerate.....	0.0424	0.0308	0.1730	(18, 25)
C <sub>10</sub> H <sub>8</sub> , naphthalene.....	0.0513			(13.1)
C <sub>10</sub> H <sub>16</sub> O <sub>2</sub> , isosafrol.....	0.0455*			(18)
C <sub>10</sub> H <sub>16</sub> O <sub>2</sub> , safrol.....	0.0434*			(18)
C <sub>10</sub> H <sub>12</sub> O <sub>2</sub> , eugenol.....	0.0377			(18)
C <sub>12</sub> H <sub>10</sub> , diphenyl.....	0.0610			(13.1)
C <sub>12</sub> H <sub>12</sub> N <sub>2</sub> , benzidine.....	0.0298			(13.1)
C <sub>14</sub> H <sub>10</sub> , anthracene.....	0.0421			(13.1)

\*  $m = 1.75$ . † Into N<sub>2</sub>. ‡ Into O<sub>2</sub>,  $D_0 = 0.0633$ ,  $m = 1.75$  (19).  
 § Value of  $m$  is not known.

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## COEFFICIENTS OF DIFFUSION IN LIQUIDS

H. R. BRUINS

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## Abbreviations and Conventions

$\Delta$ .—Defined by the equation  $\frac{\partial c}{\partial t} = \Delta \frac{\partial^2 c}{\partial x^2}$  where  $c$  is the concentration of the diffusing substance at the time  $t$  and  $x$  is the distance in the direction of the diffusion. The diffusion coefficient,  $\Delta$ , ("true" diffusion coefficient), is thus a function of  $c$ . In the following tables these "true" diffusion coefficients are in all cases marked with an asterisk and they correspond to the concentration given in the  $c$ -column of the table, this concentration being also marked with an asterisk.

All unmarked values in the  $\Delta$ -column of the tables represent some kind of "mean" value of  $\Delta$  over a range of concentration: they correspond to a diffusion from an initial concentration,  $c_0$ , (appearing in the  $c$ -column) into the pure solvent (unless otherwise indicated). These "mean" values depend also on the method employed and in some cases on the type of apparatus used; values obtained by different methods are therefore not comparable.

As far as possible the experimental methods employed in determining these "mean" values are indicated by Roman numerals as follows:

- I. Method of steady state.
- II. Second method of Graham (27, 93).
- III. Method of Stefan-Schuhmeister (118).
- IV. First method of Graham (114, 143).
- V. Indicator method (2, 127).

$c = 0^*$  indicates diffusion in very dilute solution.  $\Delta$  is then practically identical with  $\Delta_\infty$  (diffusion coefficient for infinite dilution). Temperature coefficient  $\alpha = \frac{\Delta_1 - \Delta_2}{\Delta_1(t_1 - t_2)}$ , where  $t_1 > t_2$ .

## Units

Values of  $\Delta$  are in cm<sup>2</sup>/sec. Values of  $c$  are in gram-moles per liter except in the case of electrolytes where they are in g-equiv. per liter.

## Accuracy

The values following the  $\pm$  sign indicate (a) in the case of the "true"  $\Delta$ , the estimated possible error in the absolute value; resp. (b) in the case of the "mean"  $\Delta$ ; the possible deviation from the correct value for the experimental method employed. The actual errors will probably not exceed these values. The reliability of the  $\Delta$  values is indicated in many cases as follows:

Symbol.....	A	B	C	D	E	F
Error probably $< \pm$ .....	2%	3%	5%	7%	10%	(?)

## DIFFUSION IN WATER† (OR IN A GIVEN AQUEOUS SOLUTION)

## 1. ELEMENTARY SUBSTANCES—A-TABLE

Cl<sub>2</sub>‡

$t$ , °C	$c_0$ (resp. $c^*$ )	$10^5 \Delta$	Method	Lit.
12	0.1	1.4	II	(42)
16	0.12§	1.26		(74)

Br<sub>2</sub>

12	0.1	0.9	II	(42)
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H<sub>2</sub>; cf. (6, 43, 66)

10	0*	4.3*F		(75)
16	0*	4.7*F		(74)
21	0*	5.2*F		(74)

I<sub>2</sub>;¶ cf. (17, 42)

$t$ , °C	$c_0$	$10^5 \Delta$	C, KI	Method	Lit
20	0.046	1.15A	1N	II	(90)
		1.25A	2N		
		1.31A	3N		
		1.35A	4N		

† For most of the radioactive substances, v. Vol. I, p. 364.

‡ Hydrolyzed! § Saturated at 1 atm. || Probably too low.

¶ In KI. For  $\Delta$  in solutions of NH<sub>4</sub>Br, NH<sub>4</sub>I, NaBr, NaI and KBr. v. (90).



**I<sub>2</sub>—(Continued)**

<i>t</i> , °C	<i>c</i> <sub>0</sub>	10 <sup>5</sup> Δ	<i>C</i> , KI	Method	Lit.
25	0.05	1.25B	0.25 <i>N</i>		(40)
		1.25B	0.5 <i>N</i>		
		1.38B	1.0 <i>N</i>		
		1.46B	2.0 <i>N</i>		
		1.48B	3.0 <i>N</i>		
		1.48B	4.5 <i>N</i>		

**N<sub>2</sub>; cf. (43)**

<i>t</i> , °C	<i>c</i> <sub>0</sub> (resp. <i>c</i> <sup>*</sup> )	10 <sup>5</sup> Δ	<i>C</i> , NaCl, %	Method	Lit.
19	0*	1.95*E	20		(3)
	0*	1.8*E	30		
	0*	1.8*E	40		
22	0*	2.02*E	0		(74)

**O<sub>2</sub>; cf. (43, 66, 74)**

18.0	0*	1.98* ± 0.04	1		(18, 19)
18	0*	1.7*E	20		(3)
	0*	1.6*E	30		(3)
	0*	1.1*?	40		(3)

**Rn; cf. (141)**

18	0*	1.14* ± 0.07			(112)
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**2. CHEMICAL COMPOUNDS—B-TABLE**

Standard Arrangement (v. Vol. III, p. viii)

**HCl;† cf. (4, 34, 35, 36, 52, 59, 68, 114, 122, 140)**

<i>t</i> , °C	<i>c</i> <sub>0</sub> (resp. <i>c</i> <sup>*</sup> )	10 <sup>5</sup> Δ	Method	Lit.
0	9	2.7	II, IV	(115, 116)
	7	2.4		
	4	2.1		
	3	2.0		
	2	1.8		
	0.4	1.6		
5	6	2.4	II, IV	(115, 116)
	1.3	1.9		
	0.4	1.8		
10	9	3.3	II, IV	(115, 116)
	6.5	3.0		
	2.5	2.5		
	0.8	2.2		
	0.5	2.1		
	4.5	3.0		
13	0.8	2.6(?)	II, IV	(115, 116)
15	2.5	2.9	II, IV	(115, 116)
12.0†	1.0	2.27 ± 0.02	II	(93)
	0.5	2.24 ± 0.02		
	0.25	2.26 ± 0.02		
	0.1	2.29 ± 0.03		
	0.05	2.31 ± 0.03		
	0.02	2.34 ± 0.04		
	0.01	2.38 ± 0.04		
	0.5	2.44 ± 0.03		
16.0†	0.1	2.47 ± 0.03	II	(93)
13	0.175*	2.3*E		(134)
	2.0*	3.8*E		
19	3.2*	4.5*E		(134)
	1.0*	3.0*E		
	0.3*	2.7*E		
	0.2*	2.7*E		
	0.1*	2.5*E		

**H<sub>2</sub>S (in 20% gelatin); cf. (43)**

15	0*	1.4*F		(66)
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†  $\alpha = 0.019$ , between 12 and 16°C (93).**H<sub>2</sub>SO<sub>4</sub>; cf. (34, 35, 36, 52, 59, 140)**

<i>t</i> , °C	<i>c</i> <sub>0</sub> (resp. <i>c</i> <sup>*</sup> )	10 <sup>5</sup> Δ	Method	Lit.
8	1.0	1.24D	II	(115)
	0.55	1.17D		
	0.24	1.17D		
	0.16	1.13D		
	0.08	1.25D		
	8.6	1.50D		
13	0.6	1.44D	II	(115)
	0.3	1.34D		
	1.0	1.21 ± 0.06		
10	2.0	1.26 ± 0.06	II	(4)
18	10*	2.7*E		(134)
	5*	2.2*E		
	3*	1.9*E		
	1*	1.6*E		
	0.4*	1.5*E		
	0.05*	1.5*†		
20.0	2.0	1.50B	II	(103)
	1.5	1.56B		
	1.0	1.58B		
	0.75	1.60B		
	0.5	1.62B		
	0.25	1.63B		
	0.1	1.73B		

**N<sub>2</sub>O; cf. (66)**

16	0*	1.54*E		(75)
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**NH<sub>3</sub>; cf. (43, 66, 92, 140)**

5	3.5	1.24C	II	(115)
	0.7	1.24C		
8	1.0	1.36C	II	(4)
12	1.0	1.64B	II	(4)
15	1.0	1.77C	II	(1)
8	†	1.08E	I	(75)
10	†	1.14E	I	(75)
15	†	1.26E	I	(75)

**HNO<sub>3</sub>; cf. (35, 52, 59, 140)**

6	3.0	1.78C	II	(115)
	1.0	1.82C		
	0.84	1.75C		
9	2.0	2.04C	II	(115)
	1.5	2.06C		
	0.8	2.01C		
	0.6	1.94C		
	0.1	2.00C		
	0.55	2.21B		
12	2.0	2.49B	II	(103)
	1.5	2.47B		
	1.0	2.50B		
	0.5	2.58A		
	0.25	2.59A		
	0.1	2.60A		
20	0.05	2.62A		(134)
	4.0*	2.9*E		
	1.0*	2.7*E		
	0.4*	2.6*E		
	0.1*	2.4*E		

**NH<sub>4</sub>NO<sub>3</sub>; cf. (52)**

15	0.4	1.3F	II	(59)
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† Probably too low. ‡ Satd. at 1 atm.



**NH<sub>4</sub>Cl; cf. (52, 59, 84, 115, 140)**

<i>t</i> , °C	<i>c</i> <sub>0</sub> (resp. <i>c</i> <sup>*</sup> )	10 <sup>4</sup> Δ	Method	Lit.
0†	1.0	0.93A	V	(126)
20†	1.0	1.64A	V	(126)
30†	1.0	2.07A	V	(126)
40†	1.0	2.50A	V	(126)
8	4.5	1.3E	III	(118)
12	2.3	1.5E	III	(118)
	5.0	1.7E		
18	0.2	1.5C	IV	(114)

**NH<sub>4</sub>HSO<sub>4</sub> (59)**Diffuses as a mixture of (NH<sub>4</sub>)<sub>2</sub>SO<sub>4</sub> and H<sub>2</sub>SO<sub>4</sub>**(NH<sub>4</sub>)<sub>2</sub>SO<sub>4</sub>; cf. (46, 47, 58)**

<i>t</i> , °C	<i>c</i> <sub>0</sub> (resp. <i>c</i> <sup>*</sup> )	10 <sup>4</sup> Δ	Method	Lit.
0†	1.0	0.47B	V	(125)
20†	1.0	0.92B	V	(125)
15	0.5	0.73F	II	(59)

**H<sub>3</sub>PO<sub>4</sub>; cf. (52)**

<i>t</i> , °C	<i>c</i> <sub>0</sub> (resp. <i>c</i> <sup>*</sup> )	10 <sup>4</sup> Δ	Method	Lit.
20.0	3.0	0.75 ± 0.03	II	(103)
	2.0	0.76 ± 0.03		
	1.5	0.79 ± 0.03		
	1.0	0.80 ± 0.03		
	0.5	0.85 ± 0.03		
	0.25	0.89 ± 0.03		

**CO<sub>2</sub>; cf. (43, 66, 147, 148, 149, 150)**

<i>t</i> , °C	<i>c</i> <sub>0</sub> (resp. <i>c</i> <sup>*</sup> )	10 <sup>4</sup> Δ	Method	Lit.
10	0*	1.46*B		(74, 75, 120)
15	0*	1.60*B		(74, 75, 120)
20	0*	1.77*B		(74, 75, 120)
18.0	0*	1.71* ± 0.03		(18, 19)

For other C-compounds, v. p. 69.

**Pb(NO<sub>3</sub>)<sub>2</sub>**

<i>t</i> , °C	<i>c</i> <sub>0</sub> (resp. <i>c</i> <sup>*</sup> )	10 <sup>4</sup> Δ	Method	Lit.
12	0.8	0.76C	II	(115)
	0.2	0.82C		

**ZnCl<sub>2</sub>**

<i>t</i> , °C	<i>c</i> <sub>0</sub> (resp. <i>c</i> <sup>*</sup> )	10 <sup>4</sup> Δ	Method	Lit.
15	0.1	0.73F	II	(59)

**ZnSO<sub>4</sub>; cf. (46, 47, 59, 84, 118)**

<i>t</i> , °C	<i>c</i> <sub>0</sub> (resp. <i>c</i> <sup>*</sup> )	10 <sup>4</sup> Δ	Method	Lit.
0	4*	0.14*F		(119, 142)
15	1*	0.27*F		(119, 142)
18	4*	0.24*F		(119, 142)
8	2.75*	0.20*		
	1.25*	0.23*		
	0.75*	0.26*		
	0.375*	0.31*		
	0.125*	0.33*		
	0.025*	0.42*		
	0.005*	0.44*		
20	3.0*	0.38*		
	0.55*	0.42*		
	0.05*	0.54*		

**Zn(NO<sub>3</sub>)<sub>2</sub>; cf. (59)**

<i>t</i> , °C	<i>c</i> <sub>0</sub> (resp. <i>c</i> <sup>*</sup> )	10 <sup>4</sup> Δ	Method	Lit.
20	4.0*	0.89*E		(134)
	0.7*	0.92*E		
	0.1*	1.02*E		

**Zn(CHO<sub>2</sub>)<sub>2</sub>, Formate**

<i>t</i> , °C	<i>c</i> <sub>0</sub> (resp. <i>c</i> <sup>*</sup> )	10 <sup>4</sup> Δ	Method	Lit.
19.0	0.5*	0.54*(?)		(119)

**Zn(C<sub>2</sub>H<sub>3</sub>O<sub>2</sub>)<sub>2</sub>, Acetate**

<i>t</i> , °C	<i>c</i> <sub>0</sub> (resp. <i>c</i> <sup>*</sup> )	10 <sup>4</sup> Δ	Method	Lit.
0	2.0*	0.14*(?)		(119)
18	2.0*	0.24*(?)		

† In 0.5 % agar.

**CdSO<sub>4</sub>**

<i>t</i> , °C	<i>c</i> <sub>0</sub> (resp. <i>c</i> <sup>*</sup> )	10 <sup>4</sup> Δ	Method	Lit.
19.0	2.0*	0.28*(?)		(119)

**HgCl<sub>2</sub>**

<i>t</i> , °C	<i>c</i> <sub>0</sub> (resp. <i>c</i> <sup>*</sup> )	10 <sup>4</sup> Δ	Method	Lit.
10	0.25	0.68	II	(130)
13	0.25	0.76	II	(130)
18	0.25	0.92	II	(130)

**CuCl<sub>2</sub>**

<i>t</i> , °C	<i>c</i> <sub>0</sub> (resp. <i>c</i> <sup>*</sup> )	10 <sup>4</sup> Δ	Method	Lit.
6	2.0	0.50E	III	(118)

**CuSO<sub>4</sub>; cf. (60, 107, 125)**

<i>t</i> , °C	<i>c</i> <sub>0</sub> (resp. <i>c</i> <sup>*</sup> )	10 <sup>4</sup> Δ	Method	Lit.
5	1.6	0.24F	III	(118)
	2.2	0.25F		
8	1.1	0.27F	III	(118)
	2.2	0.25F		
14	2.5	0.31 ± 0.02	IV	(143)
	1.2	0.35 ± 0.02		
	0.4	0.39 ± 0.02	IV	(143)
10	2.0*	0.20*		
	1.0*	0.26*		
	0.3*	0.31*		
	0.1*	0.40*		
17	2.0*	0.26*		
	1.0*	0.29*		
	0.5*	0.34*		
	0.3*	0.38*		
	0.1*	0.45*		
20	0.5*	0.38*		
	0.1*	0.50*		
	0.01*	0.58*		

**AgNO<sub>3</sub>**

<i>t</i> , °C	<i>c</i> <sub>0</sub> (resp. <i>c</i> <sup>*</sup> )	10 <sup>4</sup> Δ	Method	Lit.
3	0.14	0.94C	II, IV	(115, 116)
7	5	0.7C	II, IV	(115, 116)
	2	0.88C		
	0.3	1.04C		
9	0.02*	1.1*E		(134)
12	3.9*	0.6*E		(134)
	0.9*	1.0*E		
	0.1*	1.15*E		
12.0	0.1	1.22 ± 0.04	II	(77)
14.0	0.05	1.33 ± 0.04	II	(77)
15.0	0.17	1.28 ± 0.04	II	(77)

**MnCl<sub>2</sub>**

<i>t</i> , °C	<i>c</i> <sub>0</sub> (resp. <i>c</i> <sup>*</sup> )	10 <sup>4</sup> Δ	Method	Lit.
15	0.5	0.72F	II	(59)

**MnSO<sub>4</sub>**

<i>t</i> , °C	<i>c</i> <sub>0</sub> (resp. <i>c</i> <sup>*</sup> )	10 <sup>4</sup> Δ	Method	Lit.
15	0.5	0.35F	II	(59)

**Mn(NO<sub>3</sub>)<sub>2</sub>**

<i>t</i> , °C	<i>c</i> <sub>0</sub> (resp. <i>c</i> <sup>*</sup> )	10 <sup>4</sup> Δ	Method	Lit.
15	0.3	0.7F	II	(59)

**FeCl<sub>2</sub>; cf. (59)**

<i>t</i> , °C	<i>c</i> <sub>0</sub> (resp. <i>c</i> <sup>*</sup> )	10 <sup>4</sup> Δ	Method	Lit.
15	0.2	0.73	II	(14)
	0.2	0.69†		
	0.2	0.61‡		

**FeSO<sub>4</sub>**

<i>t</i> , °C	<i>c</i> <sub>0</sub> (resp. <i>c</i> <sup>*</sup> )	10 <sup>4</sup> Δ	Method	Lit.
15	0.5	0.39F	II	(59)

**Fe(NO<sub>3</sub>)<sub>3</sub>**

<i>t</i> , °C	<i>c</i> <sub>0</sub> (resp. <i>c</i> <sup>*</sup> )	10 <sup>4</sup> Δ	Method	Lit.
15	0.3	0.57	II	(14)

† In 0.1N HCl. ‡ In 20 % HCl.



**CoCl<sub>2</sub>† cf. (113, 118)**

<i>t</i> , °C	<i>c</i> <sub>0</sub> (resp. <i>c</i> <sup>*</sup> )	10 <sup>5</sup> Δ	Method	Lit.
0	0.1	0.5		(140)
20	0.1	1.0		(140)
40	0.1	1.5		(140)

**NiCl<sub>2</sub>‡**

0	0.16	0.5		(140)
20	0.16	1.0		(140)
40	0.16	1.7		(140)

**Ni(NO<sub>3</sub>)<sub>2</sub> (113)****UO<sub>2</sub>(NO<sub>3</sub>)<sub>2</sub>**

18	0.4	0.67	II	(71)
	0.4	0.51§		

**H<sub>3</sub>BO<sub>3</sub>**

20.0	1.5	0.94 ± 0.03	II	(103)
	1.0	0.94 ± 0.03		
	0.75	0.95 ± 0.03		
	0.5	0.96 ± 0.03		
	0.1	1.01¶		
	0.05	1.10¶		

**MgCl<sub>2</sub>|| cf. (36, 59, 140)**

0	1.0	0.61A	V	(126)
20	1.0	1.12A	V	(126)
30	1.0	1.42A	V	(126)
40	1.0	1.73A	V	(126)

**MgSO<sub>4</sub>; cf. (46, 47, 59, 118, 122)**

0	1.0	0.27B	V	(125)
20	1.0	0.51B	V	(125)
7	2.2	0.35D	II	(115)
	1.0	0.35D		
	0.5	0.38D		
10	3.2	0.31D	II	(115)
	0.4	0.39D		

**Mg(NO<sub>3</sub>)<sub>2</sub>**

15	0.5	0.8F	II	(59)
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**Ca(OH)<sub>2</sub>†**

0	0.2	0.9		(140)
20	0.2	1.6		(140)
40	0.2	2.5		(140)

**CaCl<sub>2</sub>; cf. (118, 140)**

9	5	0.82D	II	(115)
	0.4	0.74D		
	0.3	0.80D		
0	1.0	0.65A	V	(126)
20	1.0	1.16A	V	(126)
30	1.0	1.48A	V	(126)
40	1.0	1.83A	V	(126)

**Ca(NO<sub>3</sub>)<sub>2</sub>**

14	0.30	0.81 ± 0.03	II	(77)
	0.14	0.85 ± 0.03		

† In 2 % agar, probably ca. 10 % lower than in water.

‡ In 2 % agar, probably ca. 10 % + lower than in water.

§ In 8N HNO<sub>3</sub>.

¶ Probably too high.

|| In 0.5 % agar.

**Sr(OH)<sub>2</sub>†**

<i>t</i> , °C	<i>c</i> <sub>0</sub> (resp. <i>c</i> <sup>*</sup> )	10 <sup>5</sup> Δ	Method	Lit.
0	0.1	0.8		(140)
20	0.1	1.5		(140)
40	0.1	2.3		(140)

**Ba(OH)<sub>2</sub>†**

0	0.08	0.9		(140)
20	0.08	1.5		(140)
40	0.08	2.4		(140)

**BaCl<sub>2</sub>; cf. (86, 140)**

0‡	1.0	0.66A	V	(126)
	0.1	0.68A		
20‡	1.0	1.16A	V	(126)
	0.1	1.22A		
30‡	1.0	1.48A		
40‡	1.0	1.80A		
8	2.0	0.76D	II	(115)
	0.3	0.75D		

**RaCl<sub>2</sub>§**

18	0*	0.77*		(70)
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**LiOH;† cf. (59)**

0	0.3	0.7		(140)
20	0.3	1.3		(140)
40	0.3	2.1		(140)

**LiCl;|| cf. (34, 36, 59, 118, 126)**

For Δ in solutions of various organic substances, see (100).

9.0	4.2	0.84	±0.01— 0.02	II	(77, 81, 93)
	2.0	0.81			
	1.0	0.81			
	0.5	0.80			
	0.25	0.81			
	0.1	0.83			
	0.05	0.85			
11.0	0.02	0.91 ± 0.03		II	(77, 81, 93)
	0.01	0.93 ± 0.03			
13.0	0.55	0.92 ± 0.03			
15.0	0.28	0.97 ± 0.03			
18.0	0.5	1.06 ± 0.02			
	0.05	1.12 ± 0.02			
20.0¶	1.0	1.12B			(86)
30.0¶	1.0	1.32B			(86)

**LiBr**

8	4.3	1.0E	III	(118)
	2.3	0.9E		

**LiI**

10	1.2	0.92E	III	(118)
13	0.9	0.90E		

**Li<sub>2</sub>SO<sub>4</sub>**

15	0.6	0.53F	II	(59)
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**LiNO<sub>3</sub>**

15	0.5*	1.0*F	II	(59)
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**NaOH; \*\* cf. (4, 34, 35, 59, 115, 134, 140)**

9	0.02*	1.2*F		(134)
12	4.0*	1.1*E		(134)
	1.0*	1.2*E		
	0.1*	1.3*E		

† In 2 % agar, probably ca. 10 % less than in water.

‡ In 0.5 % agar.

§ In 0.01N HCl.

|| α = 0.027 between 9 and 18°C; cf. (93). ¶ In 2 % agar.

\*\* α = 0.023 between 8 and 15°C; cf. (93).



## NaOH.—(Continued)

$t, ^\circ\text{C}$	$c_0$ (resp. $c^*$ )	$10^5\Delta$	Method	Lit.
12	0.5	1.33C	II	(4)
13	2.0	1.23C	II	(4)
	0.54	1.37C		
8.0	0.5	$1.19 \pm 0.01$	II	(93)
	0.1	$1.22 \pm 0.01$		
15.0	2.0	$1.36 \pm 0.02$	II	(93)
	1.0	$1.39 \pm 0.02$		
	0.5	$1.41 \pm 0.02$		
	0.2	$1.45 \pm 0.02$		
	0.1	$1.47 \pm 0.02$		
	0.05	$1.49 \pm 0.04$		
	0.02	$1.51 \pm 0.04$		
	0.01	$1.54 \pm 0.04$		

NaCl; † cf. (4, 13, 15, 36, 44, 59, 67, 68, 111, 115, 116, 122, 126, 127, 129, 134, 137, 140, 147)

18.0	0.05*	$1.26^* \pm 0.02$		(24, 25, 26)
	0.1*	$1.24^* \pm 0.02$		
	0.2*	$1.21^* \pm 0.02$		
	0.4*	$1.20^* \pm 0.02$		
	0.6*	$1.21^* \pm 0.02$		
	0.8*	$1.22^* \pm 0.02$		
	1.0*	$1.24^* \pm 0.02$		
	1.5*	$1.27^* \pm 0.02$		
	2.0*	$1.30^* \pm 0.02$		
	2.5*	$1.33^* \pm 0.02$		
	3.0*	$1.36^* \pm 0.02$		
	3.5*	$1.39^* \pm 0.02$		
	4.0*	$1.43^* \pm 0.02$		
	4.5*	$1.46^* \pm 0.02$		
	5.0*	$1.50^* \pm 0.02$		
	5.4*	$1.54^* \pm 0.02$		
5.0	5.4	0.83	II	(93)
	2.75	0.83		
	0.9	0.84		
	0.5	0.84		
	0.23	0.86		
	0.1	0.87		
	0.05	$0.89 \pm 0.03$		
	0.02	$0.90 \pm 0.03$		
	0.01	$0.91 \pm 0.03$		
18.0	0.9	$1.23 \pm 0.02$	II	(93)
	0.1	$1.30 \pm 0.02$		
5.0†	0.05	0.89	II	(93, 136)
10.0†	0.05	1.03	II	(93, 136)
15.0†	0.05	1.19	II	(93, 136)
20.0†	0.05	1.39	II	(93, 136)
25.0†	0.05	1.61	II	(93, 136)
30.0†	0.05	1.84	II	(93, 136)
18.0	0.4	$1.17 \pm 0.02$	I	(24)
	0.6	$1.18 \pm 0.02$		
	0.8	$1.19 \pm 0.02$		
	1.0	$1.20 \pm 0.02$		
	1.5	$1.21 \pm 0.02$		
	2.0	$1.23 \pm 0.02$		
	2.5	$1.24 \pm 0.02$		
	3.0	$1.25 \pm 0.02$		
20‡	1.0	1.27B		(86)
30‡	1.0	1.55B		

†  $\alpha = 0.025$  between 18 and 5°C; cf. (93). ‡ Interpolated. § In 2% agar.

## NaBr

$t, ^\circ\text{C}$	$c_0$ (resp. $c^*$ )	$10^5\Delta$	Method	Lit.
8	4.0	0.9	D to E	III
10	3.7	1.0		
13	3.0	1.1		

NaI; cf. (59, 81)

8	1.0	0.9	D to E	III	(118)
	2.0	1.0			
13	0.086	$1.13 \pm 0.04$	II		(77)
	0.24	$1.09 \pm 0.04$			

NaNO<sub>3</sub>; cf. (52, 58, 118)

3	5.5	0.66C	II, IV	(115, 116)
	1.2	0.72C		
11	3	0.89C	II, IV	(115, 116)
	2	0.94C		
	0.5	0.97C		
13	6.0	0.89C	II, IV	(115, 116)
	0.5	1.04C		
10	3.9*	0.73*E		(134)
	0.9*	0.91*E		
	0.1*	0.97*E		
	0.02*	0.98*E		
15	0.3	1.0F	II	(59)

Na<sub>2</sub>SO<sub>3</sub>

15	0.5	0.59F	II	(59)
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Na<sub>2</sub>SO<sub>4</sub>; † cf. (59, 118, 122)

0	1.0	0.36B	V	(123)
20	1.0	0.77B	V	(123)

Na<sub>2</sub>S<sub>2</sub>O<sub>3</sub>

10	1.1	0.62D	IV	(116)
	0.2	0.74D		

NaHSO<sub>4</sub> (59)

Diffuses as a mixture of Na<sub>2</sub>SO<sub>4</sub> and H<sub>2</sub>SO<sub>4</sub>.

Na<sub>2</sub>CO<sub>3</sub>; † cf. (58)

5	0.5	0.51D	II	(115)
5	2.0	0.37E	III	(110)
9	2.4	0.43E	III	(118)
20	3.5	0.70E	III	(118)
15	0.6	0.77F	II	(59)

Na<sub>2</sub>C<sub>2</sub>O<sub>4</sub>, Oxalate

6	0.3	0.60	II	(115)
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NaCHO<sub>2</sub>, Formate

8	0.4	0.80C	IV	(116)
10	0.9	0.84C		

NaC<sub>2</sub>H<sub>3</sub>O<sub>2</sub>, Acetate; cf. (59, 122)

5	0.25	0.6C	II	(114)
12	0.4–0.06	0.76C	II	(78, 115)
	0.03–0.01	0.82C		
14	0.125	0.87C	II	(77)
14	0.105	0.86C	II	(81)

Na<sub>2</sub>C<sub>4</sub>H<sub>4</sub>O<sub>6</sub>, Tartrate

4	0.25	0.50C	II	(115)
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NaC<sub>7</sub>H<sub>5</sub>O<sub>2</sub>S, Sulfobenzoate

15	0.3	0.8C	II	(116)
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† In 0.5% agar.

‡ Hydrolyzed.



## KOH;† cf. (34, 35, 59, 115, 140)

$t, ^\circ\text{C}$	$c_0$ (resp. $c^*$ )	$10^5\Delta$	Method	Lit.
10.0	0.45	$1.76 \pm 0.02$	II	(93)
	0.05	$1.81 \pm 0.02$		
18.0	1.8	$2.19 \pm 0.02$	II	(93)
	0.9	$2.15 \pm 0.02$		
	0.45	$2.13 \pm 0.03$		
	0.2	$2.13 \pm 0.03$		
	0.1	$2.15 \pm 0.03$		
	0.05	$2.17 \pm 0.04$		
	0.02	$2.19 \pm 0.04$		
	0.01	$2.20 \pm 0.05$		
13	3.0	2.3C	II	(4)
	1.0	2.05C		
	0.75	2.05C		
	0.5	2.0C		
	0.375	2.0C		
13	4.0*	2.8*E		(134)
	1.0*	2.1*E		
	0.1*	2.0*E		
	0.02*	1.9*E		

KCl; cf. (34, 36, 59, 63, 67, 86, 111, 118, 122, 126, 134, 137, 140)

For  $\Delta$  in solutions of various organic substances, see (100)

18.0	0.05*	$1.55^* \pm 0.03$		(24, 25, 26)
	0.1*	$1.52^* \pm 0.03$		
	0.2*	$1.50^* \pm 0.03$		
	0.4*	$1.49^* \pm 0.03$		
	0.6*	$1.53^* \pm 0.03$		
	0.8*	$1.56^* \pm 0.03$		
	1.0*	$1.59^* \pm 0.03$		
	1.5*	$1.66^* \pm 0.03$		
	2.0*	$1.74^* \pm 0.03$		
	2.5*	$1.82^* \pm 0.03$		
	3.0*	$1.92^* \pm 0.03$		
	3.5*	$2.02^* \pm 0.03$		
	4.0*	$2.13^* \pm 0.03$		
0	2.7†	$1.05 \pm 0.03$	I	(24, 61, 62)
13	2.7†	$1.39 \pm 0.03$	I	(24, 61, 62)
18	2.7†	$1.63 \pm 0.03$	I	(24, 61, 62)
24	2.7†	$1.77 \pm 0.03$	I	(24, 61, 62)
0	1.3‡	$0.99 \pm 0.03$	I	(24)
15	1.3‡	$1.46 \pm 0.03$	I	(24)
18	1.3‡	$1.53 \pm 0.03$	I	(24)
24	1.3‡	$1.79 \pm 0.03$	I	(24)
18.0	0.4	$1.46 \pm 0.03$	I	(24)
	0.6	$1.48 \pm 0.03$		
	0.8	$1.49 \pm 0.03$		
	1.0	$1.51 \pm 0.03$		
	1.5	$1.54 \pm 0.03$		
	2.0	$1.58 \pm 0.03$		
	2.5	$1.62 \pm 0.03$		
0§	1.0	0.94A	V	(126)
20§	1.0	1.64A	V	(126)
30§	1.0	2.07A	V	(126)
40§	1.0	2.50A	V	(126)
5.0	3.6	$1.09 \pm 0.02$	II	(93, 95, 102)
	1.0¶	$1.08 \pm 0.02$		
	0.5¶	$1.09 \pm 0.02$		

†  $\alpha = 0.021$  between 18 and  $10^\circ\text{C}$ ; cf. (93).‡ For  $c_0 = 2.7$ :  $\Delta_t = \Delta_0(1 + 0.02t + 0.0005t^2)$ .

§ In 0.5% agar.

¶  $10^5\Delta = A[1 + 0.0242(t - 18) + 0.0001(t - 18)^2]$ , where

For $c_0 =$	0.1	0.25	0.5	1.0
A =	1.595	1.549	1.537	1.536

## KCl.—(Continued)

$t, ^\circ\text{C}$	$c_0$ (resp. $c^*$ )	$10^5\Delta$	Method	Lit.
6.0	1.8	$1.10 \pm 0.02$	II	(93, 95, 102)
	0.25¶	$1.14 \pm 0.02$		
7.0	0.1¶	$1.18 \pm 0.02$	II	(93, 95, 102)
	0.05	$1.20 \pm 0.03$		
9.0	0.02	$1.28 \pm 0.03$	II	(93, 95, 102)
	0.01	$1.30 \pm 0.03$		
14.0	1.0¶	$1.38 \pm 0.02$	II	(93, 95, 102)
	0.5¶	$1.38 \pm 0.02$		
	0.25¶	$1.39 \pm 0.02$		
18.0	1.0¶	$1.54 \pm 0.01$	II	(93, 95, 102)
	0.1¶	$1.60 \pm 0.01$		
20.0	1.0¶	$1.61 \pm 0.02$	II	(93, 95, 102)
	0.25¶	$1.63 \pm 0.02$		
24.0	1.0¶	$1.78 \pm 0.02$	II	(93, 95, 102)
	0.25¶	$1.79 \pm 0.02$		
30.0	1.0¶	$2.00 \pm 0.02$	II	(93, 95, 102)
	0.5¶	$2.01 \pm 0.02$		
	0.25¶	$2.03 \pm 0.02$		
20.00	0.1	$1.676 \pm 0.005$	II	(16, 27, 31)

## KBr

12	1.5	1.4D	III	(118)
	2.2	1.4D		
	2.3	1.4D		
20	1.4	1.6D	III	(118)
	3.2	1.8D		
	4.6	1.8D		

## KI;† cf. (52, 59)

8.0	5.3	$1.37 \pm 0.02$	II	(93)
	2.7	$1.27 \pm 0.02$		
	0.9	$1.21 \pm 0.02$		
	0.46	$1.22 \pm 0.02$		
	0.18	$1.22 \pm 0.02$		
	0.09	$1.23 \pm 0.02$		
	0.045	$1.25 \pm 0.04$		
	0.02	$1.26 \pm 0.04$		
	0.01	$1.29 \pm 0.04$		
15.0	0.46	$1.46 \pm 0.02$	II	(93)
	0.046	$1.49 \pm 0.02$		
9	1.4	1.3D	III	(118)
	5.4	1.6D		
16	1.1	1.5D	III	(118)
	1.4	1.5D		
	2.4	1.6D		
	4.0	1.8D		
	6.0	2.0D		
13.0	0.09	$1.45 \pm 0.05$	II	(77)

K<sub>2</sub>SO<sub>4</sub>

15	0.4	0.87F	II	(59)
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K<sub>2</sub>SO<sub>4</sub>; cf. (46, 47, 59, 118)

0‡	1.0	0.47C	V	(125)
20‡	1.0	0.91B	V	(125)
9	0.02*	0.9*E		(134)
20	0.95*	0.9*E		(134)
	0.25*	1.0*E		
	0.05*	1.1*E		
	0.005*	1.2*E		

†  $\alpha = 0.0235$  between 15 and  $8^\circ\text{C}$ ; cf. (93). ‡ In 0.5% agar.



**KHSO<sub>4</sub>**; (59, 134)Diffuses as a mixture of K<sub>2</sub>SO<sub>4</sub> and H<sub>2</sub>SO<sub>4</sub>.**KNO<sub>3</sub>**; cf. (52, 58, 59, 115, 118, 134)

<i>t</i> , °C	<i>c</i> <sub>0</sub> (resp. <i>c</i> <sup>*</sup> )	10 <sup>3</sup> Δ	Method	Lit.
18.0	0.05*	1.46* ± 0.02		(24, 25, 26)
	0.1*	1.43* ± 0.02		
	0.2*	1.39* ± 0.02		
	0.4*	1.34* ± 0.02		
	0.6*	1.30* ± 0.02		
	0.8*	1.27* ± 0.02		
	1.0*	1.24* ± 0.02		
	1.5*	1.19* ± 0.02		
	2.0*	1.15* ± 0.02		
	2.5*	1.17* ± 0.02		
0.0	1.0†	0.87 ± 0.03	I	(24)
	0.5†	0.89 ± 0.03	I	(24)
15.0	1.0†	1.26 ± 0.03	I	(24)
16.0	0.5†	1.29 ± 0.03	I	(24)
18.0	0.05	1.49 ± 0.02	I	(24)
	0.1	1.46 ± 0.02		
	0.2	1.43 ± 0.02		
	0.4	1.40 ± 0.02		
	0.6	1.37 ± 0.02		
	0.8	1.35 ± 0.02		
	1.0	1.33 ± 0.02		
	2.0	1.25 ± 0.02		
19.0	1.0†	1.35 ± 0.03	I	(24)
	0.5†	1.42 ± 0.03		
24.0	1.0†	1.54 ± 0.03	I	(24)
25.0	0.5†	0.55 ± 0.03	I	(24)

**K<sub>2</sub>CO<sub>3</sub>**; cf. (58, 59)

5	10.0	0.60E	III	(118)
9	3.0	0.68E		
21	2.9	0.8E		

**KC<sub>2</sub>H<sub>3</sub>O<sub>2</sub>**;† Acetate

14	2.0	1.01	II	(77)
	1.0	1.13		

**K<sub>2</sub>Fe(CN)<sub>6</sub>**

16	0.3	0.94	II	(14)
	0.3	0.46‡		

**K<sub>4</sub>Fe(CN)<sub>6</sub>**

16	0.4	1.06	II	(14)
	0.4	0.34‡		

**K<sub>2</sub>Cr<sub>2</sub>O<sub>7</sub>**

12.0	0.063	0.96C	IV	(143)
	0.03	0.99C		
18.0	0.15	1.09C	IV	(143)
	0.05	1.17C		
	0.016	1.17C		
	0.007	1.24C		

† For *c*<sub>0</sub> = 1.0: Δ = 0.87(1 + 0.023*t* + 0.00032*t*<sup>2</sup>) × 10<sup>-3</sup>.For *c*<sub>0</sub> = 0.5: Δ = 0.89(1 + 0.24*t* + 0.00027*t*<sup>2</sup>) × 10<sup>-3</sup>.

‡ Hydrolysed.

§ In 0.1N KCl.

**RbCl and CsCl** (91)

Relative determinations; at 18°C, KCl: RbCl: CsCl = 1.00: 1.02: 1.05 (semi-quantitative).

**C-TABLE**

C-Arrangement (v. Vol. III, p. viii)

**CH<sub>2</sub>O<sub>2</sub>**, Formic acid; cf. (133, 140)

<i>t</i> , °C	<i>c</i> <sub>0</sub> (resp. <i>c</i> <sup>*</sup> )	10 <sup>3</sup> Δ	Method	Lit.
9	1.0	1.02C	II	(4)
15	0*	1.04*E to F		(136)

**CH<sub>4</sub>N<sub>2</sub>O**, Urea; cf. (13, 37, 68, 105, 116)

10.0	1.0	0.89B	II	(96)
	0.25	0.96B		
12.0	0.7	0.96B	II	(77, 78)
	0.5	0.96B		
	0.35	0.97B		
	0.25	0.97B		
	0.15	0.98B		
	0.10	0.97B		
	0.05	0.99B		
15	0*	0.94*(?)		(136)
20.0	2.0	1.14B	II	(96)
	1.0	1.14B		
	0.25	1.18B		

**CH<sub>3</sub>O**, Methyl alcohol; cf. (104)

15	0*	1.28*C		(136)
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**CH<sub>3</sub>N<sub>2</sub>O<sub>3</sub>**;† Ammonium carbonate

15	0.7	1.17F	II	(59)
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**C<sub>2</sub>H<sub>2</sub>O<sub>4</sub>**, Oxalic acid; cf. (52, 140)

4	0.4	0.73D	II, IV	(114, 115)
8	0.8	0.82D	II, IV	(114, 115)
14	0.25	1.09C	II, IV	(114, 115)
	0.16	1.17C		
	0.1	1.23C		
10	1.5	0.67E	II	(4)
	0.75	0.83E		
	0.15	0.95E		
15	0*	1.1*F		(136)
20.0	2.0	0.91 ± 0.02	II	(102)
	1.5	0.98 ± 0.02		
	1.0	1.01 ± 0.02		
	0.75	1.06 ± 0.02		
	0.50	1.14 ± 0.02		
	0.25	1.26 ± 0.03		
	0.1	1.41 ± 0.03		

**C<sub>2</sub>H<sub>3</sub>Cl<sub>3</sub>O<sub>2</sub>**, Chloral hydrate

9	0.4	0.64	IV	(114)
15	0*	0.58*D		(136)

**C<sub>2</sub>H<sub>3</sub>N**, Acetonitrile

15	0*	1.26*C		(136)
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**C<sub>2</sub>H<sub>4</sub>N<sub>4</sub>**, Dicyanodiamide

10.0	0.25	0.77 ± 0.03	II	(96)
20.0	0.40	0.99 ± 0.04	II	(96)
	0.20	1.04 ± 0.04		

**C<sub>2</sub>H<sub>4</sub>O<sub>2</sub>**;† Acetic acid; cf. (1, 104, 114, 115, 136, 140)

9	4.0	0.69	C to D	II	(4)
	2.0	0.72			
	1.0	0.76			
	0.5	0.78			
	0.25	0.80			

† Hydrolysed.

‡ α = 0.028 between 18 and 12°C; cf. (94).



$C_2H_4O_2$ —(Continued)

$t, ^\circ C$	$c_0$ (resp. $c^*$ )	$10^5 \Delta$	Method	Lit.
12.5†	1.0	$0.82 \pm 0.02$	II	(94)
	0.5	$0.84 \pm 0.02$		
	0.2	$0.85 \pm 0.02$		
	0.1	$0.87 \pm 0.02$		
	0.05	$0.88 \pm 0.02$		
	0.02	$0.89 \pm 0.03$		
	0.01	$0.91 \pm 0.04$		
18.0†	1.0	$0.96 \pm 0.02$	II	(94)
	0.1	$1.03 \pm 0.02$		
17	0.93	$0.92 \pm 0.03$	II	(41)
	0.65	$0.94 \pm 0.03$		
	0.47	$0.95 \pm 0.03$		

 $C_2H_5NO$ , Acetamide; cf. (104)

10.0	5.0	$0.67 \pm 0.03$	II	(96)
	0.5	$0.79 \pm 0.03$		
20.0	10.0	$0.79 \pm 0.03$	II	(96)
	5.0	$0.92 \pm 0.03$		
	2.0	$1.00 \pm 0.03$		
	1.0	$1.03 \pm 0.03$		
	0.5	$1.04 \pm 0.03$		
15	0*	$0.96^*C$		(136)

 $C_2H_5O$ , Ethyl alcohol; cf. (104)

10	3.75*	$0.50^*E$		(134)
	0.75*	$0.70^*E$		
	0.25*	$0.78^*E$		
	0.05*	$0.83^*E$		
15	0*	$1.00^*C-D$		(136)
16	2.0	$0.90D$	II	(1)

 $C_2H_7NO_2$ , † Ammonium acetate

15	0.4	1.1F	II	(59)
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 $C_2H_4Cl_2O$ , 1,1'-Dichloropropyl alcohol

15	0*	$0.75^*C-D$		(136)
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 $C_3H_8O$ , Allyl alcohol

15	0*	$0.90^*C-D$		(136)
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 $C_3H_7O_2$ , Propionic acid; cf. (140) $C_3H_7ClO_2$ , 3-Chloro-1, 2-dihydroxypropane

15	0*	$0.76^*C-D$		(136)
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 $C_3H_7NO_2$ , Urethane

15	0*	$0.80^*C-D$		(136)
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 $C_3H_8O$ , *n*-Propyl alcohol

15	0*	$0.87^*C-D$		(136)
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 $C_3H_8O_3$ , § Glycerol; cf. (68, 101, 104, 105)

10.0	2.0	$0.56 \pm 0.02$	II	(96)
	1.0	$0.55 \pm 0.02$		
	0.5	$0.57 \pm 0.02$		
	0.25	$0.61 \pm 0.02$		
	0.125	$0.63 \pm 0.02$		
20.0	2.0	$0.75 \pm 0.03$	II	(96)
	1.0	$0.77 \pm 0.03$		
	0.5	$0.78 \pm 0.03$		
	0.25	$0.82 \pm 0.03$		
	0.125	$0.83 \pm 0.03$		
15	0*	$0.72^*C-D$		(136)

†  $\alpha = 0.028$  between 18 and 12°C.

‡ Hydrolyzed.

§  $\alpha = 0.033$ , between 20 and 10°C; cf. (96). For diffusion into solutions of KCl and LiCl, s. (101). $C_4H_2N_2O_4$ , Alloxan; cf. (108)

$t, ^\circ C$	$c_0$ (resp. $c^*$ )	$10^5 \Delta$	Method	Lit.
10.0	1.0	$0.48 \pm 0.02$	II	(96)
	0.25	$0.49 \pm 0.03$		
20.0	1.0	$0.61 \pm 0.03$	II	(96)
	0.5	$0.64 \pm 0.03$		
	0.25	$0.65 \pm 0.03$		
	0.125	$0.66 \pm 0.03$		

 $C_4H_4O_4$ , Succinic acid; cf. (114)

20.0	1.0	$0.70 \pm 0.03$	II	(102)
	0.75	$0.73 \pm 0.03$		
	0.5	$0.76 \pm 0.03$		
	0.25	$0.79 \pm 0.03$		
	0.1	$0.82 \pm 0.04$		

 $C_4H_6O_6$ , Tartaric acid; cf. (52, 105, 114, 116, 140)

3	0.25	$0.41D$	II	(115)
5	0.25	$0.43D$	II	(115)
	0.7	$0.43D$		
9	0.7	$0.52D$	II	(115)
15	0*	$0.61^*C-D$		(136)
18	6.0*	$0.34^*E$		(134)
	2.45*	$0.50^*E$		
	0.95*	$0.57^*E$		
	0.35*	$0.62^*E$		
	0.1*	$0.64^*E$		
	0.0125*	$0.66^*E$		

 $C_4H_6O_6$ , *dl*-Tartaric acid

5	0.7	$0.45D$	II	(115, 116)
	0.2	$0.44D$		

 $C_4H_8O_2$ , *n*-Butyric acid (140) $C_4H_{10}O$ , *n*-Butyl alcohol

15	0*	$0.77^*C-D$		(136)
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 $C_5H_5N$ , Pyridine

15	0*	$0.58^*C-D$		(136)
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 $C_6H_{10}O_5$ , Arabinose

9.0	0.5	$0.41 \pm 0.02$	II	(94)
	0.25	$0.44 \pm 0.02$		
	0.1	$0.46 \pm 0.02$		
20.0	0.5	$0.64 \pm 0.03$	II	(94)
	0.1	$0.69 \pm 0.03$		

 $C_6H_{12}O$ , Isoamyl alcohol

15	0*	$0.69^*C-D$		(136)
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 $C_6H_{12}O_4$ , Pentaerythritol

10.0	0.4	$0.47 \pm 0.02$	II	(96)
	0.2	$0.49 \pm 0.02$		
20.0	0.4	$0.67 \pm 0.02$	II	(96)
	0.2	$0.68 \pm 0.02$		

 $C_6H_3N_3O_7$ , Picric acid; cf. (45)

15	0*	$0.69^*C-D$		(136)
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 $C_6H_6O$ , Phenol

12	<0.2*	$0.64^*(?)$		(136)
16	<0.2*	$0.74^*(?)$		(136)
20	<0.2*	$0.84^*(?)$		(136)

 $C_6H_6O_2$ , Hydroquinol

15	0*	$0.66^*C-D$		(136)
20.0	0.7	$0.74 \pm 0.02$	II	(96)
	0.5	$0.76 \pm 0.02$		
	0.25	$0.77 \pm 0.02$		



**C<sub>6</sub>H<sub>6</sub>O<sub>2</sub>, Resorcinol**

<i>t</i> , °C	<i>c</i> <sub>0</sub> (resp. <i>c</i> <sup>*</sup> )	10 <sup>5</sup> Δ	Method	Lit.
10	1.0	0.51 ± 0.02	II	(96)
	0.25	0.53 ± 0.02		
20	2.0	0.61 ± 0.02	II	(96)
	1.0	0.69 ± 0.02		
	0.5	0.72 ± 0.02		
	0.25	0.75 ± 0.03		
	0.125	0.76 ± 0.03		
15	0*	0.65 *C-D		(136)

**C<sub>6</sub>H<sub>6</sub>O<sub>3</sub>, Pyrogallol**

15	0*	0.56 *C-D		(136)
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**C<sub>6</sub>H<sub>8</sub>O<sub>7</sub>, Citric acid; cf. (140)**

5	0.3	0.39D	II	(114, 115)
9	1.1	0.48D	II	(114, 115)

**C<sub>6</sub>H<sub>12</sub>N<sub>4</sub>, Hexamethylenetetramine**

21	0.6	0.6	II	(104)
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**C<sub>6</sub>H<sub>12</sub>O<sub>6</sub>, Glucose**

15	0*	0.52 *C-D		(136)
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**C<sub>6</sub>H<sub>14</sub>O<sub>6</sub>, Mannitol; cf. (37, 114)**

0†	0.3	0.26 ± 0.02	IV	(117)
10†	0.3	0.40 ± 0.02	IV	(117)
20†	0.3	0.56 ± 0.02	IV	(117)
30†	0.3	0.72 ± 0.03	IV	(117)
40†	0.3	0.90 ± 0.04	IV	(117)
50†	0.3	1.10 ± 0.04	IV	(117)
60†	0.3	1.32 ± 0.05	IV	(117)
70†	0.3	1.56 ± 0.06	IV	(117)
10.0	0.5	0.39 ± 0.02	II	(96)
	0.25	0.40 ± 0.02		
	0.125	0.42 ± 0.02		
20.0	0.5	0.53 ± 0.02	II	(96)
	0.25	0.56 ± 0.02		
	0.125	0.58 ± 0.02		
15	0*	0.50 *C-D		(136)

**C<sub>7</sub>H<sub>6</sub>O<sub>4</sub>, Gallic acid (105)****C<sub>7</sub>H<sub>8</sub>O<sub>2</sub>, *o*-Hydroxybenzyl alcohol**

20.0	1.0	0.60 ± 0.02	II	(96)
	0.5	0.67 ± 0.03		
	0.25	0.72 ± 0.03		

**C<sub>8</sub>H<sub>10</sub>N<sub>4</sub>O<sub>2</sub>, Caffeine**

10.0	0.05	0.41 ± 0.03	II	(94)
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**C<sub>8</sub>H<sub>11</sub>NO<sub>3</sub>, Ecgonine**

20.0	1.0	0.61 ± 0.03	II	(96)
	0.5	0.66 ± 0.03		
	0.1	0.70 ± 0.03		

**C<sub>10</sub>H<sub>14</sub>N<sub>2</sub>, Nicotine**

10.0	1.0	0.28 ± 0.02	II	(94)
	0.5	0.37 ± 0.02		
	0.1	0.46 ± 0.02		
20.	1.0	0.32 ± 0.02	II	(94)
	0.5	0.43 ± 0.02		
	0.1	0.53 ± 0.04		

**C<sub>12</sub>H<sub>22</sub>O<sub>11</sub>, Lactose**

10.0	0.2	0.32 ± 0.02	II	(94)
	0.1	0.32 ± 0.02		
20.0	0.2	0.41 ± 0.02	II	(94)
	0.1	0.43 ± 0.02		
15	0*	0.38 *D		(136)

† Interpolated.

**C<sub>12</sub>H<sub>22</sub>O<sub>11</sub>, Maltose; cf. (105)**

<i>t</i> , °C	<i>c</i> <sub>0</sub> (resp. <i>c</i> <sup>*</sup> )	10 <sup>5</sup> Δ	Method	Lit.
10.0	0.5	0.29 ± 0.01	II	(94)
	0.25	0.31 ± 0.02		
	0.1	0.32 ± 0.02		
20.0	0.5	0.38 ± 0.01	II	(94)
	0.25	0.41 ± 0.02		
	0.1	0.42 ± 0.02		
15	0*	0.38 *D		(136)

**C<sub>12</sub>H<sub>22</sub>O<sub>11</sub>, † Saccharose; cf. (4, 104, 105, 122)**

12.0	2.0	0.25	±0.01 to 0.02	(94, 102)
	1.5	0.28		
	1.0	0.30		
	0.5	0.325		
	0.25	0.34		
	0.1	0.35		
	0.075	0.355		
14.0	1.0	0.33		
	0.5	0.35		
	0.25	0.36		
20.0	2.0	0.32	±0.01 to 0.02	(94, 102)
	1.0	0.38		
	0.5	0.41		
	0.25	0.43		
24.0	1.0	0.435		
	0.25	0.49		
29.0	1.0	0.50		
	0.5	0.53		
	0.25	0.55		
15	0*	0.38 *D		(136)
18	2.0*	0.15 *E		(134)
	1.0*	0.28 *E		
	0.3*	0.36 *E		
	0.005*	0.38 *E		

**C<sub>13</sub>H<sub>18</sub>O<sub>7</sub>, Salicin**

20.0	0.12	0.46 ± 0.03	II	(96)
	0.06	0.49 ± 0.03		

**C<sub>14</sub>H<sub>10</sub>O<sub>9</sub>, Tannin (105, 122)****C<sub>15</sub>H<sub>32</sub>O<sub>16</sub>, Raffinose; cf. (105)**

11.0	0.25	0.27	±0.01	II	(94)
	0.125	0.27			
	0.1	0.28			
	0.075	0.28			
	0.05	0.28			
20.0	0.25	0.33	±0.01 to 0.02	II	(94)
	0.1	0.36			
	0.05	0.36			
15	0*	0.33 *E			(136)

**Colloids**

Only the order of magnitude has significance  
Amylum (Starch)

20	5%†	0.067		(96)
	2.5%†	0.072		
	1.25%†	0.08		
	5-8%‡	0.24(?)		

† Δ<sub>t</sub> = Δ<sub>20</sub>(1 + 0.029(*t* - 20) + 0.0005(*t* - 20)<sup>2</sup>).

‡ Powder-like.

§ Dough-like.



## Colloids.—(Continued)

## Inulin

$t, ^\circ\text{C}$	$c_0$ (resp. $c^*$ )	$10^5\Delta$	Method	Lit.
20	0.01(?)	0.16		(96)

## Dextrin; cf. (105)

10	1.0	0.079		(96)
	0.5	0.081		
	0.25	0.088		
	0.1	0.090		
	0.075	0.090		
20	1.0	0.11		(96)
	0.5	0.12		
	0.25	0.12		
	0.125	0.12		

## Gum arabic; cf. (122)

20	5%	0.23		(96)
	2.5%	0.24		

For several proteins and ferments, *v.* (37, 69, 79, 122).

### NON-AQUEOUS SOLUTIONS DIFFUSION IN METHYL ALCOHOL

## A-B-TABLE

 $I_2$ 

$t, ^\circ\text{C}$	$c_0$	$10^5\Delta$	Method	Lit.
9	0.1	1.52A	II	(90)
20	0.1	1.82A		

## LiCl

14	0.65	0.75	B to C	II	(81)
	0.25	0.85			
	0.15	0.92			
	0.07	0.92			

## NaI

14	0.2	1.00	B to C	II	(81)
	0.15	1.02			
	0.07	1.03			

 $\text{NaC}_2\text{H}_3\text{O}_2$ , Acetate

14	0.3	0.84C	II	(81)
	0.2	0.87C		
	0.1	0.91C		

## KI

14	0.25	1.11	B to C	II	(81)
	0.15	1.09			
	0.05	1.15			

 $\text{KC}_2\text{H}_3\text{O}_2$ , Acetate

14	0.3	0.86C	II	(81)
	0.2	0.85C		
	0.1	0.97C		

C-TABLE, VALUES OF  $10^5\Delta^\dagger$ 

$\text{CCl}_4$ , Carbon tetrachloride: 1.70\* (136).  
 $\text{CHBr}_3$ , Bromoform: 1.57\*; 20°,  $c_0 = 1.0$ ,  $10^5\Delta = 1.89 \pm 0.04$ ;  $c_0 = 0.5$ ,  $10^5\Delta = 1.93 \pm 0.06$  (98).  
 $\text{CHCl}_3$ , Chloroform: 2.07\* (136).  
 $\text{CHI}_3$ , Iodoform: 1.33\* (136).  
 $\text{CH}_2\text{ClBr}$ , Chlorobromomethane: 2.50\* (136).  
 $\text{CH}_2\text{I}_2$ , Methylene iodide: 1.68\* (136).  
 $\text{CH}_2\text{O}_2$ , Formic acid: 1.92\* (136).  
 $\text{CH}_3\text{NO}_2$ , Nitromethane: 16°,  $c_0 = 3.3$ ,  $10^5\Delta = 2.53\text{D}$  (39).  
 $\text{CH}_4\text{N}_2\text{O}$ , Urea: 1.24\* (136).

<sup>†</sup> Unless otherwise stated, the temperature is 15°C,  $c^* = ca. 1\%$  and the reliability of  $\Delta$  is probably D, E or F in all determinations by Thoevert (136).

$\text{C}_2\text{HBr}_3\text{O}$ , Bromal: 0.72\* (136).  
 $\text{C}_2\text{HBr}_3\text{O}_2$ , Tribromoacetic acid: 1.23\* (136).  
 $\text{C}_2\text{HCl}_3\text{O}_2$ , Trichloroacetic acid: 1.45\* (136).  
 $\text{C}_2\text{H}_2\text{Cl}_2\text{O}_2$ , Dichloroacetic acid: 1.36\* (136).  
 $\text{C}_2\text{H}_2\text{O}_4$ , Oxalic acid: 1.46\* (136).  
 $\text{C}_2\text{H}_3\text{BrO}_2$ , Bromoacetic acid: 1.33\* (136).  
 $\text{C}_2\text{H}_3\text{ClO}_2$ , Chloroacetic acid: 1.52\* (136).  
 $\text{C}_2\text{H}_3\text{Cl}_3\text{O}_2$ , Chloral hydrate: 1.16\* (136).  
 $\text{C}_2\text{H}_3\text{N}$ , Acetonitrile: 2.64\* (136).  
 $\text{C}_2\text{H}_4\text{Br}_2$ , Ethylene bromide: 1.95\* (136).  
 $\text{C}_2\text{H}_4\text{Cl}_2$ , Ethylene chloride: 2.21\* (136).  
 $\text{C}_2\text{H}_4\text{I}_2$ , Ethylene iodide: 1.56\* (136).  
 $\text{C}_2\text{H}_4\text{O}_2$ , Acetic acid: 1.54\* (136).  
 $\text{C}_2\text{H}_5\text{Br}$ , Ethyl bromide: 2.40\* (136).  
 $\text{C}_2\text{H}_5\text{I}$ , Ethyl iodide: 2.16\* (136).  
 $\text{C}_2\text{H}_5\text{NO}$ , Acetamide: 1.50\* (136).  
 $\text{C}_2\text{H}_5\text{NO}_3$ , Ethyl nitrate: 2.20\* (136).  
 $\text{C}_3\text{H}_5\text{Br}$ , 3-Bromopropylene: 2.22\* (136).  
 $\text{C}_3\text{H}_5\text{BrO}_2$ , Bromopropionic acid: 1.35\* (136).  
 $\text{C}_3\text{H}_5\text{Cl}_3$ , 1, 2, 3-Trichloropropane: 1.76\* (?) (136).  
 $\text{C}_3\text{H}_5\text{I}$ , 3-Iodopropylene: 1.72\* (136).  
 $\text{C}_3\text{H}_5\text{IO}_2$ , Iodopropionic acid: 1.36\* (136).  
 $\text{C}_3\text{H}_6\text{Cl}_2\text{O}$ , 1, 1'-Dichlorohydrin: 1.36\* (136).  
 $\text{C}_3\text{H}_6\text{O}$ , Allyl alcohol: 1.80\* (136).  
 $\text{C}_3\text{H}_6\text{O}$ , Acetone: 19°,  $c_0 = 3.4$ ,  $10^5\Delta = 2.57\text{D}$  (39).  
 $\text{C}_3\text{H}_7\text{O}_2$ , Propionic acid: 1.62\* (136).  
 $\text{C}_3\text{H}_7\text{O}_3$ , Lactic acid: 1.36\* (136).  
 $\text{C}_3\text{H}_7\text{ClO}_2$ , 1-Chlorohydrin: 1.30\* (136).  
 $\text{C}_3\text{H}_7\text{NO}_2$ , Urethane: 1.41\* (136).  
 $\text{C}_3\text{H}_8\text{O}_2$ , Propylene glycol: 1.24\* (136).  
 $\text{C}_3\text{H}_8\text{O}_3$ , Glycerol: 1.15\* (136).  
 $\text{C}_4\text{H}_5\text{Cl}_3\text{O}_2$ , Ethyl trichloroacetate: 1.44\* (136).  
 $\text{C}_4\text{H}_6\text{O}_6$ , Tartaric acid: 0.94\* (136).  
 $\text{C}_4\text{H}_7\text{ClO}_2$ , Ethyl chloroacetate: 1.77\* (136).  
 $\text{C}_4\text{H}_8\text{O}_2$ , Ethyl acetate: 2.10\* (136); 18°,  $c_0 = 2.3$ ,  $10^5\Delta = 2.0\text{D}$  (39).  
 $\text{C}_4\text{H}_{10}\text{O}$ , Ethyl ether: 2.00\* (136).  
 $\text{C}_4\text{H}_{10}\text{O}_4\text{S}$ , Diethyl sulfate: 1.56\* (136).  
 $\text{C}_4\text{H}_{11}\text{N}_2\text{O}_4\text{S}$ , Ethylamine sulfate: 0.92\* (136).  
 $\text{C}_5\text{H}_4\text{N}_4\text{O}_3$ , Uric acid: 1.79\* (136).  
 $\text{C}_5\text{H}_4\text{O}_2$ , Furfural: 1.70\* (136).  
 $\text{C}_5\text{H}_5\text{N}$ , Pyridine: 1.58\* (136); 15°,  $c_0 = 0.5$ ,  $10^5\Delta = 1.64 \pm 0.06$ ,  $c_0 = 0.2$ ,  $10^5\Delta = 1.56 \pm 0.06$  (129).  
 $\text{C}_5\text{H}_{10}\text{I}_2$ , 2, 3-Diiodopentane: 1.57\* (136).  
 $\text{C}_5\text{H}_{11}\text{I}$ , Isoamyl iodide: 1.76\* (136).  
 $\text{C}_5\text{H}_{12}\text{O}$ , Isoamyl alcohol: 1.34\* (136).  
 $\text{C}_6\text{Cl}_6$ , Hexachlorobenzene: 1.31\* (136).  
 $\text{C}_6\text{H}_2\text{Cl}_4$ , Tetrachlorobenzene: 1.49\* (136).  
 $\text{C}_6\text{H}_3\text{Br}_3$ , Tribromobenzene: 1.49\* (136).  
 $\text{C}_6\text{H}_3\text{Br}_3\text{O}$ , 2, 4, 6-Tribromophenol: 1.12\* (136).  
 $\text{C}_6\text{H}_3\text{Cl}_3\text{O}$ , 2, 4, 6-Trichlorophenol: 1.21\* (136).  
 $\text{C}_6\text{H}_3\text{N}_3\text{O}_7$ , 2, 4, 6-Trinitrophenol: 1.32\* (136).  
 $\text{C}_6\text{H}_4\text{BrNO}_2$ , Bromonitrobenzene: 1.43\* (136).  
 $\text{C}_6\text{H}_4\text{Br}_2$ , *p*-Dibromobenzene: 1.55\* (136).  
 $\text{C}_6\text{H}_4\text{ClNO}_2$ , Chloronitrobenzene: 1.68\* (136).  
 $\text{C}_6\text{H}_4\text{Cl}_2$ , *p*-Dichlorobenzene: 1.80\* (136).  
 $\text{C}_6\text{H}_4\text{N}_2\text{O}_4$ , *m*-Dinitrobenzene: 1.56\* (136).  
 $\text{C}_6\text{H}_4\text{N}_2\text{O}_5$ , 2, 4-Dinitrophenol: 1.40\* (136).  
 $\text{C}_6\text{H}_4\text{O}_2$ , Quinone: 1.84\* (136).  
 $\text{C}_6\text{H}_5\text{Br}$ , Bromobenzene: 1.75\* (136).  
 $\text{C}_6\text{H}_5\text{BrO}$ , Bromophenol: 1.34\* (136).  
 $\text{C}_6\text{H}_5\text{Cl}$ , Chlorobenzene: 2.07\* (136).  
 $\text{C}_6\text{H}_5\text{ClO}$ , Chlorophenol: 1.32\* (136).  
 $\text{C}_6\text{H}_5\text{I}$ , Iodobenzene: 1.65\* (136).  
 $\text{C}_6\text{H}_5\text{NO}_2$ , Nitrobenzene: 1.81\* (136); 16°,  $c_0 = 0.8$ ,  $10^5\Delta = 1.7\text{D}$  (39).



$\text{C}_6\text{H}_5\text{NO}_2$ , Nitrophenol:  $1.38^*$  (136).  
 $\text{C}_6\text{H}_6$ , Benzene:  $15^\circ$ , for  $c_0 = 2.0, 1.0$  and  $0.5$ ,  $10^5\Delta = 2.12 \pm 0.08, 2.22 \pm 0.08$  and  $2.20 \pm 0.08$ , resp. (II) (129).  
 $\text{C}_6\text{H}_5\text{BrN}$ , Bromoaniline:  $1.41^*$  (136).  
 $\text{C}_6\text{H}_5\text{ClN}$ , Chloroaniline:  $1.37^*$  (136).  
 $\text{C}_6\text{H}_5\text{N}_2\text{O}_2$ , *m*-Nitroaniline:  $1.14^*$  (136).  
 $\text{C}_6\text{H}_5\text{O}$ , Phenol:  $1.4^*$  (136).  
 $\text{C}_6\text{H}_5\text{O}_2$ , Hydroquinol:  $1.25^*$  (136).  
 $\text{C}_6\text{H}_5\text{O}_3$ , Pyrogallol:  $1.08^*$  (136).  
 $\text{C}_6\text{H}_7\text{N}$ , Aniline:  $1.49^*$  (136).  
 $\text{C}_6\text{H}_5\text{ClN}$ , Aniline hydrochloride:  $1.19^*$  (136).  
 $\text{C}_6\text{H}_{11}\text{Cl}_2\text{O}_2$ , Dichloroacetal:  $1.63^*$  (136).  
 $\text{C}_6\text{H}_{11}\text{ClO}_2$ , Chloroacetal:  $1.47^*$  (136).  
 $\text{C}_6\text{H}_{11}\text{O}_2$ , Acetal:  $1.96^*$  (136).  
 $\text{C}_7\text{H}_5\text{ClO}_2$ , Chlorobenzoic acid:  $1.29^*$  (136).  
 $\text{C}_7\text{H}_5\text{NO}_2$ , *m*-Nitrobenzaldehyde:  $1.24^*$  (136).  
 $\text{C}_7\text{H}_5\text{NO}_4$ , Nitrobenzoic acid:  $1.15^*$  (136).  
 $\text{C}_7\text{H}_5\text{O}$ , Benzaldehyde:  $1.66^*$  (136).  
 $\text{C}_7\text{H}_5\text{O}_2$ , Salicyl aldehyde:  $1.75^*$  (136).  
 $\text{C}_7\text{H}_5\text{O}_3$ , Benzoic acid:  $1.31^*$  (136).  
 $\text{C}_7\text{H}_5\text{O}_4$ , Salicylic acid:  $1.21^*$  (136).  
 $\text{C}_7\text{H}_5\text{O}_5$ , Gallic acid:  $0.76^*$  (136).  
 $\text{C}_7\text{H}_5\text{O}$ , Anisole:  $1.96^*$  (136).  
 $\text{C}_7\text{H}_7\text{N}$ , Benzylamine:  $1.21^*$  (136).  
 $\text{C}_7\text{H}_{11}\text{O}_2$ , Isoamyl acetate:  $1.60^*$  (136).  
 $\text{C}_8\text{H}_6\text{O}_4$ , Phthalic acid:  $1.30^*$  (136).  
 $\text{C}_8\text{H}_8\text{O}_2$ , Phenyl acetate:  $1.62^*$  (136).  
 $\text{C}_8\text{H}_8\text{O}_3$ , Anisaldehyde:  $1.50^*$  (136).  
 $\text{C}_8\text{H}_8\text{O}_4$ , Vanillin:  $1.00^*$  (136).  
 $\text{C}_8\text{H}_8\text{O}_5$ , Methyl salicylate:  $1.56^*$  (136).  
 $\text{C}_8\text{H}_9\text{NO}$ , Acetanilide:  $1.50^*$  (136).  
 $\text{C}_8\text{H}_{13}\text{N}_2\text{O}$ , Acetylphenylhydrazine:  $1.04^*$  (136).  
 $\text{C}_8\text{H}_{10}\text{O}$ , Xylenol:  $1.33^*$  (136).  
 $\text{C}_8\text{H}_{10}\text{O}$ , Phenetole:  $1.83^*$  (136).  
 $\text{C}_8\text{H}_7\text{N}$ , Quinoline:  $1.26^*$  (136);  $15^\circ$ ,  $c_0 = 0.5$ ,  $10^5\Delta = 1.34 \pm 0.06$ ,  $c_0 = 0.2$ ,  $10^5\Delta = 1.29 \pm 0.06$  (129).  
 $\text{C}_8\text{H}_{10}\text{O}_2$ , Ethyl benzoate:  $16^\circ$ ,  $c_0 = 0.7$ ;  $10^5\Delta = 1.4\text{E}$  (39).  
 $\text{C}_8\text{H}_{11}\text{NO}$ , Acetoluide:  $1.03^*$  (136).  
 $\text{C}_{10}\text{H}_8\text{Br}_2$ , Dibromonaphthalene:  $1.33^*$  (136).  
 $\text{C}_{10}\text{H}_8\text{Cl}_2$ , Dichloronaphthalene:  $1.52^*$  (136).  
 $\text{C}_{10}\text{H}_8\text{N}_2\text{O}_4$ , Dinitronaphthalene:  $1.32^*$  (136).  
 $\text{C}_{10}\text{H}_7\text{Br}$ ,  $\alpha$ -Bromonaphthalene:  $1.29^*$  (136).  
 $\text{C}_{10}\text{H}_7\text{Cl}$ ,  $\alpha$ -Chloronaphthalene:  $1.38^*$  (136).  
 $\text{C}_{10}\text{H}_7\text{NO}_2$ ,  $\alpha$ -Nitronaphthalene:  $1.50^*$  (136).  
 $\text{C}_{10}\text{H}_8$ , Naphthalene:  $15^\circ$ ,  $c_0 = 0.2$ ,  $10^5\Delta = 1.60 \pm 0.07$  (II) (129).  
 $\text{C}_{10}\text{H}_8\text{O}$ ,  $\alpha$ -Naphthol:  $1.10^*$  (136).  
 $\text{C}_{10}\text{H}_{12}\text{O}$ , Cumaldehyde:  $1.50^*$  (136).  
 $\text{C}_{10}\text{H}_{14}\text{O}$ , Thymol:  $1.20^*$  (136).  
 $\text{C}_{11}\text{H}_{13}\text{N}_2\text{O}$ , Antipyrine:  $1.02^*$  (136).  
 $\text{C}_{12}\text{H}_{10}$ , Diphenyl:  $15^\circ$ ,  $c_0 = 0.2$ ,  $10^5\Delta = 1.56 \pm 0.07$  (II) (129).  
 $\text{C}_{12}\text{H}_{10}\text{O}_2$ , Salol:  $1.29^*$  (136).  
 $\text{C}_{14}\text{H}_{15}\text{NO}$ , Acetyldiphenylamine:  $0.98^*$  (136).  
 $\text{C}_{14}\text{H}_{15}\text{N}$ , Dibenzylamine:  $0.84^*$  (136).  
 $\text{C}_{19}\text{H}_{14}$ , Triphenylmethane:  $15^\circ$ ,  $c = 0.05$ ,  $10^5\Delta = 0.88 \pm 0.05$  (II) (129).  
 $\text{C}_{15}\text{H}_{15}\text{N}_3\text{O}$ , Pararosaniline:  $1.09^*$  (136).  
 $\text{C}_{20}\text{H}_{14}\text{O}_4$ , Phenolphthalein:  $0.78^*$  (136).

## DIFFUSION IN ETHYL ALCOHOL

## A-B-TABLE

R<sub>n</sub>

$t, ^\circ\text{C}$	$c^*$	$10^5\Delta$	Method	Lit.
18	0*	$2.7^*(?)$		(112)

HCl; for diffusion in dilute alcohol, v. (4)

I,				
$t, ^\circ\text{C}$	$c_0$ (resp. $c^*$ )	$10^5\Delta$	Method	Lit.
8.0	0.50	0.84	II	(80)
	0.25	0.88		
	0.10	0.90		
18.0	0.25	1.10	II	(80)

CO <sub>2</sub>				
17	0*	$3.2^*\text{C-D}$		(120)

For other C-compounds, v. the C-Table *infra*.

HgCl <sub>2</sub>				
10	0.25	0.64		(130)
	0.25	0.40 (in 73 % alcohol)		
	0.25	0.29 (in 44 % alcohol)		
	0.25	0.30 (in 27 % alcohol)		
	0.25	0.52 (in 9 % alcohol)		
	0.25	0.66 (in 2.5 % alcohol)		

AgNO <sub>3</sub>				
14	0.1	$0.41 \pm 0.02$	II	(77)
	0.07	$0.41 \pm 0.02$		

Ca(NO <sub>3</sub> ) <sub>2</sub>				
14	0.25	$0.32 \pm 0.02$	II	(77)

LiCl				
14	0.5	$0.31 \pm 0.02$	II	(77, 81)
	0.3	$0.34 \pm 0.02$		
	0.15	$0.42 \pm 0.02$		
20	0.43	$0.36 \pm 0.02$	II	(77, 81)

NaOH; NaCl; for diffusion in dilute alcohol, v. (4)

NaI				
7	0.2	$0.35 \pm 0.03$	II	(77, 81)
14	0.2	$0.41 \pm 0.03$	II	(77, 81)
	0.1	$0.44 \pm 0.03$		

NaC <sub>2</sub> H <sub>3</sub> O <sub>2</sub> , Acetate				
12	0.12	$0.35 \pm 0.02$	II	(77, 81)
14	0.1	$0.38 \pm 0.02$	II	(77, 81)

C <sub>20</sub> H <sub>8-2</sub> Br <sub>4</sub> O <sub>5</sub> Na <sub>2</sub> , Eosin				
20	0.005	$0.31 \pm 0.04$	II	(97)
	0.0025	$0.27 \pm 0.02$		

KI				
14	0.09-0.03	$0.47 \pm 0.03$	II	(77, 81)

KC <sub>2</sub> H <sub>3</sub> O <sub>2</sub> , Acetate				
14	0.25	$0.38 \pm 0.02$	II	(77)
	0.20	$0.39 \pm 0.02$		
	0.15	$0.43 \pm 0.03$		

C-TABLE (ALL DATA ARE BY METHOD II AND FROM (97) EXCEPT AS OTHERWISE INDICATED)

CHBr <sub>3</sub> , Bromoform		
$t, ^\circ\text{C}$	$c_0$	$10^5\Delta$
11	1.0	0.77C
	0.5	0.80C
20	1.0	0.96C
	0.5	0.97C

CHCl <sub>3</sub> , Chloroform		
$t, ^\circ\text{C}$	$c_0$	$10^5\Delta$
11	1.0	1.19(?)
20	2.0	1.25B
	1.0	1.24B

CH <sub>3</sub> N <sub>2</sub> O, Urea		
$t, ^\circ\text{C}$	$c_0$	$10^5\Delta$
12	0.4	$0.54 \pm 0.02$ †

† Method II (78).

C <sub>2</sub> HCl <sub>3</sub> O, Chloral (in 96 % alcohol)		
$t, ^\circ\text{C}$	$c_0$	$10^5\Delta$
20	2.0	0.57C
	1.0	0.61C

C <sub>2</sub> H <sub>5</sub> NO, Acetamide (in 96 % alcohol)		
$t, ^\circ\text{C}$	$c_0$	$10^5\Delta$
11	5.0	0.39C
	2.0	0.41C
	1.0	0.44C
20	5.0	0.52C
	2.0	0.56C
	1.0	0.61C



<b>C<sub>3</sub>H<sub>8</sub>O, Allyl alcohol</b>		
<i>t</i> , °C	<i>c</i> <sub>0</sub>	10 <sup>5</sup> Δ
20	4.0	0.91C
	2.0	0.94C
	1.0	0.96C
<b>C<sub>3</sub>H<sub>8</sub>O<sub>3</sub>, Glycerol (in 96 % alcohol)</b>		
11	2.0	0.26
	1.0	0.32
20	0.5	0.36
	4.0	0.27
	2.0	0.35
	1.0	0.41
	0.5	0.49
	0.25	0.50
<b>C<sub>5</sub>H<sub>5</sub>N, Pyridine</b>		
20	2.0	1.15B
	1.0	1.14B
	0.5	1.12B
<b>C<sub>5</sub>H<sub>10</sub>O<sub>4</sub>, Monoacetin</b>		
20	4.0	0.38C
	2.0	0.46C
	1.0	0.51C
	0.5	0.52C
	0.25	0.54C
<b>C<sub>5</sub>H<sub>12</sub>O, Isoamyl alcohol</b>		
20	6.0	0.64C
	4.0	0.69C
	2.0	0.74C
	1.0	0.78C
<b>C<sub>6</sub>H<sub>5</sub>I, Iodobenzene</b>		
20	1.0	0.94A-B
	0.5	0.95A-B
	0.25	0.98A-B
<b>C<sub>6</sub>H<sub>6</sub>O, Phenol†</b>		
10	0.1*	0.64*D
15	0.1*	0.71*D
20	0.1*	0.80*D
<b>C<sub>6</sub>H<sub>6</sub>O<sub>2</sub>, Hydroquinol (in 96 % alcohol)</b>		
20	1.0	0.47C
	0.5	0.48C
	0.25	0.48C
<b>C<sub>6</sub>H<sub>6</sub>O<sub>2</sub>, Resorcinol (in 96 % alcohol)</b>		
10	2.0	0.30C
	1.0	0.30C
	0.25	0.31C

† (136); values for *c*\*.

<b>C<sub>6</sub>H<sub>8</sub>O<sub>2</sub>—(Continued)</b>		
<i>t</i> , °C	<i>c</i> <sub>0</sub>	10 <sup>5</sup> Δ
20	2.0	0.40C
	1.0	0.41C
<b>C<sub>6</sub>H<sub>14</sub>O<sub>2</sub>, Acetal</b>		
20	2.0	1.13C
	1.0	1.13C
<b>C<sub>7</sub>H<sub>8</sub>O<sub>2</sub>, <i>o</i>-Hydroxybenzyl alcohol</b>		
20	1.0	0.52C
	0.5	0.56C
	0.25	0.59C
<b>C<sub>10</sub>H<sub>7</sub>Br, <math>\alpha</math>-Bromonaphthalene (in 96 % alcohol)</b>		
11	1.0	0.52
	0.5	0.59
20	1.0	0.69
	0.5	0.76
<b>C<sub>10</sub>H<sub>16</sub>O, Camphor (in 96 % alcohol)</b>		
10	2.0	0.47C
	1.0	0.52C
20	2.0	0.62C
	1.0	0.66C
	0.5	0.68C
<b>C<sub>12</sub>H<sub>10</sub>N<sub>2</sub>, Azobenzene (in 96 % alcohol)</b>		
10	0.1	0.57C
20	0.1	0.74C
<b>C<sub>15</sub>H<sub>34</sub>O, Cetyl alcohol (in 96 % alcohol)</b>		
20	1.0	0.35C-D
<b>C<sub>18</sub>H<sub>36</sub>O<sub>2</sub>, Stearic acid</b>		
20	0.7	0.40C
	0.4	0.47C
	0.2	0.58C
<b>C<sub>22</sub>H<sub>20</sub>O<sub>13</sub>, Carminic acid (in 96 % alcohol)</b>		
20	0.06	0.14E
	0.03	0.17E
<b>C<sub>23</sub>H<sub>26</sub>N<sub>2</sub>O<sub>4</sub>, Brucine</b>		
20	0.125	0.27C
	0.062	0.28C
<b>C<sub>23</sub>H<sub>25</sub>N<sub>3</sub>, Trimethylrosaniline</b>		
20	0.02	0.67(?)
	0.01	0.93(?)
<b>C<sub>34</sub>H<sub>47</sub>NO<sub>11</sub>, Aconitine</b>		
20	0.04	0.27D

<b>I<sub>2</sub>; cf. (42)</b>				
<i>t</i> , °C	<i>c</i> <sub>0</sub> (resp. <i>c</i> *)	10 <sup>5</sup> Δ	Method	Lit.
6	0.25	1.46B	II	(80)
	0.1	1.47B		
20	0.1	1.93B		(80)
	0.05	1.95B		
9	0.1	1.62B	II	(90)

**C-TABLE, VALUES OF 10<sup>5</sup>Δ†**

CHBr<sub>3</sub>, Bromoform: 1.62\* (136); 18°, *c*<sub>0</sub> = 1.0, 10<sup>5</sup>Δ = 1.62 ± 0.05 (98).

CHCl<sub>3</sub>, Chloroform: 2.11\* (136).

CHI<sub>3</sub>, Iodoform: 1.38\* (136).

CH<sub>2</sub>O<sub>2</sub>, Formic acid: 2.16\* (136).

C<sub>2</sub>H<sub>3</sub>ClO<sub>2</sub>, Chloroacetic acid: 1.48\* (136).

C<sub>2</sub>H<sub>4</sub>Br<sub>2</sub>, Ethylene bromide: 1.97\* (136).

C<sub>2</sub>H<sub>4</sub>Cl<sub>2</sub>, Ethylene chloride: 2.45\* (136).

C<sub>2</sub>H<sub>4</sub>I<sub>2</sub>, Ethylene iodide: 1.40\* (136).

C<sub>2</sub>H<sub>4</sub>O<sub>2</sub>, Acetic acid: 1.92\* (136).

C<sub>3</sub>H<sub>5</sub>Cl<sub>3</sub>, 1, 2, 3-Trichloropropane: 1.72\* (136).

C<sub>3</sub>H<sub>8</sub>O, Propyl alcohol: 1.60\* (136).

C<sub>4</sub>H<sub>10</sub>O, Ethyl ether: 2.21\* (136).

C<sub>5</sub>H<sub>12</sub>O, Isoamyl alcohol: 1.48\* (136).

C<sub>6</sub>H<sub>3</sub>N<sub>3</sub>O<sub>7</sub>, 2, 4, 6-Trinitrophenol: 1.39\* (136).

C<sub>6</sub>H<sub>5</sub>BrNO<sub>2</sub>, Bromonitrobenzene: 1.33\* (136).

C<sub>6</sub>H<sub>4</sub>Br<sub>2</sub>, *p*-Dibromobenzene: 1.37\* (136).

C<sub>6</sub>H<sub>4</sub>ClNO<sub>2</sub>, Chloronitrobenzene: 1.70\* (136).

C<sub>6</sub>H<sub>4</sub>Cl<sub>2</sub>, *p*-Dichlorobenzene: 1.90\* (136).

C<sub>6</sub>H<sub>4</sub>N<sub>2</sub>O<sub>4</sub>, *m*-Dinitrobenzene: 1.54\* (136).

C<sub>6</sub>H<sub>4</sub>O<sub>2</sub>, Quinone: 1.68\* (136).

C<sub>6</sub>H<sub>5</sub>Br, Bromobenzene: 1.86\* (136).

C<sub>6</sub>H<sub>5</sub>BrO, Bromophenol: 1.34\* (136).

C<sub>6</sub>H<sub>5</sub>Cl, Chlorobenzene: 2.15\* (136).

C<sub>6</sub>H<sub>5</sub>ClO, Chlorophenol: 1.42\* (136).

C<sub>6</sub>H<sub>5</sub>I, Iodobenzene: 1.50\* (136).

C<sub>6</sub>H<sub>5</sub>NO<sub>2</sub>, Nitrobenzene: 1.84\* (136).

C<sub>6</sub>H<sub>5</sub>BrN, Bromoaniline: 1.41\* (136).

C<sub>6</sub>H<sub>5</sub>ClN, Chloroaniline: 1.56\* (136).

**C<sub>6</sub>H<sub>6</sub>O, Phenol†**

<i>t</i> , °C	10 <sup>5</sup> Δ	Lit.
5	1.27*	(136)
10	1.39*	
15	1.54*	
20	1.68*	
25	1.84*	

C<sub>7</sub>H<sub>6</sub>O, Benzaldehyde: 1.73\* (136).

C<sub>7</sub>H<sub>6</sub>O<sub>2</sub>, Salicylaldehyde: 1.78\* (136).

C<sub>7</sub>H<sub>6</sub>O<sub>2</sub>, Benzoic acid: 1.36\* (136).

C<sub>8</sub>H<sub>6</sub>O<sub>4</sub>, Phthalic acid: 1.37\* (136).

C<sub>8</sub>H<sub>8</sub>O<sub>2</sub>, Methyl salicylate: 1.56\* (136).

C<sub>10</sub>H<sub>6</sub>Br<sub>2</sub>, Dibromonaphthalene: 1.25\* (136).

C<sub>10</sub>H<sub>6</sub>Cl<sub>2</sub>, Dichloronaphthalene: 1.40\* (136).

C<sub>10</sub>H<sub>6</sub>N<sub>2</sub>O<sub>4</sub>, Dinitronaphthalene: 1.23\* (136).

C<sub>10</sub>H<sub>7</sub>Br,  $\alpha$ -Bromonaphthalene: 1.30\* (136).

C<sub>10</sub>H<sub>7</sub>Cl,  $\alpha$ -Chloronaphthalene: 1.20\* (136).

C<sub>10</sub>H<sub>7</sub>NO<sub>2</sub>,  $\alpha$ -Nitronaphthalene: 1.39\* (136).

C<sub>10</sub>H<sub>8</sub>, Naphthalene: 24°, *c*<sub>0</sub> = 1.3, 10<sup>5</sup>Δ = 1.22F (104).

C<sub>10</sub>H<sub>12</sub>O<sub>2</sub>, Thymoquinone: 1.20\* (136).

C<sub>12</sub>H<sub>10</sub>, Diphenyl: 26°, *c*<sub>0</sub> = 0.5, 10<sup>5</sup>Δ = 1.17F (104).

C<sub>14</sub>H<sub>13</sub>NO, Acetyldiphenylamine: 0.90\* (136).

C<sub>14</sub>H<sub>14</sub>, Dibenzyl: 26°, *c*<sub>0</sub> = 0.4, 10<sup>5</sup>Δ = 1.00F (104).

† Unless otherwise stated, the temperature is 15°C, *c*\* = ca. 1% and all values of 10<sup>5</sup>Δ have a reliability D, E or F in all determinations by Thovet (136).

**DIFFUSION IN BENZENE****A-B-TABLE****Rn**

<i>t</i> , °C	<i>c</i> <sub>0</sub> (resp. <i>c</i> *)	10 <sup>5</sup> Δ	Method	Lit.
18	0*	2.36*D		(112)
<b>Br<sub>2</sub></b>				
12	0.1	2.0		(42)



DIFFUSION IN METALS, *v. also* (88, 89, 146) and p. 77

Solvent	Solute	<i>t</i> , °C	<i>c</i> <sub>0</sub> (resp. <i>c</i> *)	10 <sup>4</sup> Δ	Lit.
Bi	Au	555	(?)	5.2	(109)
Hg	Au	11	(?)	0.8	(109); cf. (88, 89, 146)
	Cd	20.0	0*	1.520* ± 0.015	(29, 32)
		20.0	0*	1.446* ± 0.015†	(30, 33)
Pb	Au	492	ca. 30 %	3.5	(109)
		550	ca. 30 %	3.7	(109)
	Pt	492	(?)	1.96	(109)
	Rh	550	(?)	3.5	(109)
	Th-B	340	0*	2.5*	(64)
Sn	Ag	555	(?)	4.8	(109)
	Au	555	(?)	5.4	(109)
	Pb	555	(?)	3.7	(109)

† At 1500 atm.

DIFFUSION IN VARIOUS LIQUIDS, *v. also* (39)

Rn					
Solvent	<i>t</i> , °C	<i>c</i> <sub>0</sub> (resp. <i>c</i> *)	10 <sup>4</sup> Δ	Method	Lit.
C <sub>7</sub> H <sub>8</sub> , Toluene.....	18	0*	2.7*D		(112)
Br <sub>2</sub>					
CS <sub>2</sub> .....	16	0.1	3.6		(42)
I <sub>2</sub>					
CCl <sub>4</sub> .....	8	0.1	1.11	II	(90)
	20	0.1	1.36	II	(90)
CS <sub>2</sub> .....	8	0.25	2.76	II	(42, 80, 90)
		0.10	2.78		(80)
		0.05	2.79		(80)
	10	0.05	2.87	II	(80)
	16	0.1	2.96	II	(80)
	20	0.1	3.12	II	(80)
CHCl <sub>3</sub> .....	10	0.1	1.86	II	(80, 90)
		0.05	1.98		
	20	0.1	2.12	II	(80, 90)
C <sub>2</sub> H <sub>5</sub> Br, 1, 1, 2, 2-Tetra- bromoethane.....	11	0.1	0.134	II	(90)
	20	0.1	0.188	II	(90)
C <sub>2</sub> H <sub>5</sub> Br <sub>2</sub> , Ethylene bro- mide.....	12	0.1	0.72	II	(90)
	20	0.1	0.88	II	(90)
C <sub>2</sub> H <sub>5</sub> O <sub>2</sub> , Acetic acid.....	20	0.1	1.08	II	(90)
C <sub>2</sub> H <sub>5</sub> O <sub>2</sub> , Ethyl acetate.....	9	0.1	1.87	II	(90)
	20	0.1	2.15	II	(90)
C <sub>2</sub> H <sub>5</sub> O, Ethyl ether.....	7	0.5	2.68	II	(80)
		0.25	2.78		
		0.1	2.84		
C <sub>6</sub> H <sub>5</sub> Br, Bromobenzene.....	9	0.1	1.02	II	(90)
	20	0.1	1.20	II	(90)
C <sub>7</sub> H <sub>8</sub> , Toluene.....	9	0.1	1.67	II	(90)
	20	0.1	1.98	II	(90)
C <sub>7</sub> H <sub>8</sub> O, Anisole.....	8	0.1	0.88	II	(90)
	20	0.1	1.18	II	(90)
C <sub>7</sub> H <sub>14</sub> O <sub>2</sub> , Isoamyl acetate.....	9	0.1	1.01	II	(90)
	20	0.1	1.24	II	(90)
C <sub>7</sub> H <sub>14</sub> , Heptane.....	9	0.1	2.36	II	(90)
	20	0.1	2.67	II	(90)
C <sub>8</sub> H <sub>18</sub> , <i>m</i> -Xylene.....	9	0.1	1.42	II	(90)
	20	0.1	1.68	II	(90)
C <sub>8</sub> H <sub>10</sub> O, Phenetole.....	8	0.1	0.77	II	(90)
	20	0.1	0.98	II	(90)
CHBr <sub>3</sub>					
C <sub>2</sub> H <sub>5</sub> O, Acetone.....	20	1.0	2.64	II	(90)
		0.5	2.69		
		0.25	2.71		
C <sub>2</sub> H <sub>5</sub> O, <i>n</i> -Propyl alcohol.....	17	1.0	0.71	II	(90)
C <sub>2</sub> H <sub>5</sub> O, Ethyl ether.....	17	1.0	3.14	II	(90)
		0.5	3.24		
		0.25	3.21		
C <sub>2</sub> H <sub>5</sub> O, Isoamyl alcohol.....	17	1.0	0.47	II	(90)

## DIFFUSION IN VARIOUS LIQUIDS.—(Continued)

C <sub>2</sub> H <sub>2</sub> Br <sub>4</sub> , 1, 1, 2, 2-Tetrabromoethane					
Solvent	<i>t</i> , °C	<i>c</i> <sub>0</sub> (resp. <i>c</i> *)	10 <sup>4</sup> Δ	Method	Lit.
C <sub>2</sub> H <sub>2</sub> Cl <sub>4</sub> , 1, 1, 2, 2- Tetra- chloroethane.....	0.0	0.06	0.35	± 0.01 to 0.02	II (28)
	10.0	0.06	0.45		
	15.0	0.06	0.50		
	25.0	0.06	0.61		
	35.0	0.06	0.73		
	50.0	0.06	0.94		
C <sub>2</sub> H <sub>5</sub> O <sub>2</sub> , Glycerol					
C <sub>2</sub> H <sub>5</sub> O, <i>n</i> -Propyl alcohol..	18	1.0	2.38	II	(98)
C <sub>2</sub> H <sub>5</sub> O, Isoamyl alcohol..	18	1.0	0.11	II	(98)
C <sub>6</sub> H <sub>6</sub> O, Phenol					
CS <sub>2</sub> .....	19	0*	3.4*		(136)
CHCl <sub>3</sub> .....	10	0*	1.6*		(136)
C <sub>2</sub> H <sub>5</sub> O, Ethyl ether.....	19	0*	3.6*		(136)
C <sub>2</sub> H <sub>5</sub> O, Isoamyl alcohol..	19	0*	0.2*		(136)

For diffusion in anistropic liquids, *v.* (128).

For diffusion in anisotropic liquids, *v.* (128).

## LITERATURE

(For a key to the periodicals see end of volume)

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## PERMEABILITY OF SOLIDS TO GASES

FRANK PORTER

By the permeability of a solid is meant the quantity  $K$  in the equation  $\frac{dm}{dt} = -K\rho_0 \frac{\Delta p}{\Delta z} dx dy$ , where  $dm$  is the mass of gas which passes in the direction of  $z$  and in time  $dt$  through a diaphragm of the solid of area  $dx dy$  and thickness  $\Delta z$ , the difference in pressure on the two sides of the diaphragm (excess on positive side) being  $\Delta p$ ; the  $-$  sign indicates that the flow is in the direction of decreasing pressure.  $\rho_0$  is the density of the gas at  $0^\circ\text{C}$  and pressure  $= A_n$ ;  $dm/\rho_0 =$  volume of  $dm$  at  $0^\circ\text{C}$  and  $A_n$ . At very low pressures  $K$  may depend upon the pressure (12). The passage of a gas through a porous septum is approximately given by  $\frac{dm}{dt} = -K_0 \sqrt{\rho_0 \frac{\Delta p}{\Delta z}} dx dy$  (11), where  $K_0$  is independent of the nature of the gas. In the table,  $l$  denotes that the value given is for water vapor when one surface of the diaphragm is in contact with liquid water.

Unit of  $p = 1$  atm.; of  $\theta = 1^\circ\text{C}$ ; of  $K$  (metals and rubber)  $= 10^{-6} \text{ cm}^2/(\text{atm.}\cdot\text{sec})$ ; of  $K$  (glass)  $= 10^{-9} \text{ cm}^2/(\text{atm.}\cdot\text{sec})$ .

### METALS\*

#### H-Cu

$\theta$	$K$	Lit.
500	3.5	(1)
750	8	

#### H-Fe

200	0.83	(13)
300	5	
400	25	
500	100	
600	336	

#### H-Ni

400	0.95	(1)
500	3.80	
600	8.86	
700	23.8	
750	31.6	

#### H-Pd

200	400	(7)
300	1820	
400	3160	
500	4450	
600	5750	

#### H-Pt

600	0.77	(12)
700	2.0	
800	4.3	
900	10.0	
1000	17.1	
1100	30.2	

### H-Zn

$\theta$	$K$	Lit.
300	0.4	(1)

#### He-Pt-Ir

Scarcely appreciable up to  $\theta = 1420^\circ$  (3)

#### N-Mild Steel

600	0.5	(13)
700	1.6	
800	5.0	
1000	11.6	

#### O-Ag

400	0.0032	(6)
450	0.0097	
500	0.021	
550	0.057	
600	0.146	

#### CO-Mild Steel

400	0.5	(13)
500	1.6	
600	5	
700	23	
800	67	
835	133	

850,  $K$  falls suddenly almost to zero.

### VULCANIZED RUBBER†

$\theta$	$K$	Lit.
25	0.088	(4)

### H

$\theta$	$K$	Lit.
0	0.12	(4)
20	0.30	
25	0.34	
40	0.57	
60	1.02	
80	1.68	
100	2.60	

### He

0	0.075	(4)
20	0.21	
25	0.22	
40	0.36	
60	0.66	
80	1.08	
100	1.56	

### N

25	0.054	(4)
----	-------	-----

### O

25	0.150	(4)
----	-------	-----

### CO<sub>2</sub>

0	0.30	(4)
20	0.84	
25	0.98	
40	1.77	
60	3.88	
80	4.00	
100	5.30	

### C<sub>2</sub>H<sub>5</sub>Cl

25	68	(4)
----	----	-----

### CH<sub>3</sub>Cl

25	6.3	(4)
----	-----	-----

### H<sub>2</sub>O

25	16.0	(4)
25	35.0(l)	

### NH<sub>3</sub>

25	2.7	(4)
----	-----	-----

### Air

25	0.075	(4)
----	-------	-----

### GLASS

#### A-SiO<sub>2</sub>†

900	1.4	(5)
-----	-----	-----

#### H-SiO<sub>2</sub>†

300	1.9	(5)
	7	(16)
	3.5	(15)
400	17	(8)

### H-SiO<sub>2</sub>†—(Cont'd)

$\theta$	$K$	Lit.
500	6.2	(15)
	28	(8)
600	11	(15)
	50	(8)
700	17	(15)
	80	(8)
	35	(15)
800	100	(8)
	55	(15)
900	140	(8)
1000	128	(16)

### He-SiO<sub>2</sub>†

200	14	(15)
300	35	(15)
400	70	(15)
500	157	(15)
600	350	(15)
1200	210	(14)

### N-SiO<sub>2</sub>†

600	0.11	(5)
700	0.50	
800	1.68	
900	4.8	

### Pyrex

#### H

$K$  inappreciable at  $\theta = 600^\circ$

#### He

610	14	(15)
-----	----	------

#### Jena

#### H

$K$  inappreciable at  $\theta = 800^\circ$

### Thuringian

#### He

100	0.000081	(10)
200	0.009	
300	0.064	
400	0.340	
500	1.000	

### Cu†

Gas	$K/K_H$	Lit.
		$\theta = 700^\circ\text{C}$
H	1	(9)
CO	0.017	
CO <sub>2</sub>	0.0006	
H <sub>2</sub> O	0.065	



## PURE PARA RUBBER||

 $\theta = 15^\circ\text{C}$ 

Gas	$K/K_H$	Lit.	Gas	$K/K_H$	Lit.
A	0.19	(2)	CO	0.16	(2)
H	1.00		CO <sub>2</sub>	2.5	
He	0.3		C <sub>2</sub> H <sub>5</sub> OH	250	
N	0.11		H <sub>2</sub> O	16.0	
O	0.35		Air	0.17	

\* Values for Cu and relative to H are given near end of table.

† Relative values for pure Para rubber are at end of table.

‡ Quarts glass. For H, extreme values are given.

§ i. also beginning of table.

|| cf. vulcanized rubber.

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## DIFFUSION IN SOLIDS

C. H. DESCH

 $\Delta$  = Coefficient of diffusion. For definition, see Vol. I, p. 36

Diffusing system	$t, ^\circ\text{C}$	$\Delta, \text{cm}^2/\text{day}$	Lit.
Au in Pb.....	197	$76 \times 10^{-4}$	(15); agrees
	150	$43 \times 10^{-4}$	well with
	100	$2+ \times 10^{-4}$	(10)
Au in Ag.....	935	$11 \times 10^{-6}$	(16)
	885	$48 \times 10^{-6}$	(16)
	870	$37 \times 10^{-6}$	(5)
	835	$21 \times 10^{-6}$	(16)
Au (from solid solution) in Ag.....	916	$52 \times 10^{-6}$	(2)
	847	$22 \times 10^{-6}$	(2)
	767	$11 \times 10^{-6}$	(2)
Cu in Ni.....	1000	$115 \times 10^{-7}$	(8)
Ni in Cu.....	1000	$55 \times 10^{-8}$	(8)
Th in W.....	2027	$95 \times 10^{-6}$	(4)
Po in Au.....	470	$1 \times 10^{-9}$	(17)
Ra-B + C in Ag.....	470	$4 \times 10^{-7}$	(17)
Ra-B + C in Au.....	470	$8 \times 10^{-7}$	(17)
Ra-B + C in Pt.....	470	$3 \times 10^{-7}$	(17)
Zn in Cu ( $\alpha$ ).....	400	$2 \times 10^{-8}$	(8)
	324	$14 \times 10^{-6}$	(7)
	320	$47 \times 10^{-6}$	(7)
Th-B in Pb.....	310	$57 \times 10^{-7}$	(7)
	300	$25 \times 10^{-7}$	(7)
	280	$15 \times 10^{-7}$	(7)
	260	$6 \times 10^{-7}$	(7)
Po in Pb.....	310	$13 \times 10^{-6}$	(7)
Th-B in Tl.....	285	$2 \times 10^{-7}$	(7)
C in $\gamma$ -Fe.....	930	$29 \times 10^{-7}$	(14)
	930	$17 \times 10^{-7}$	(11)

## DIFFUSION OF IONS IN CRYSTALLINE SOLIDS

Na in permutite.....	20	$112 \times 10^{-6}$	(12)
Ag in permutite.....	20	$164 \times 10^{-6}$	(12)
Na in natrolite.....	20	$13 \times 10^{-6}$	(12)
Ag in Cu <sub>2</sub> S.....		1.0	(2)

## DIFFUSION OF OXYGEN INTO SILVER AT 400-630°

$$x = \frac{43054}{h} p^{1/2} T^{1/2} e^{-\frac{43232}{4t}}$$

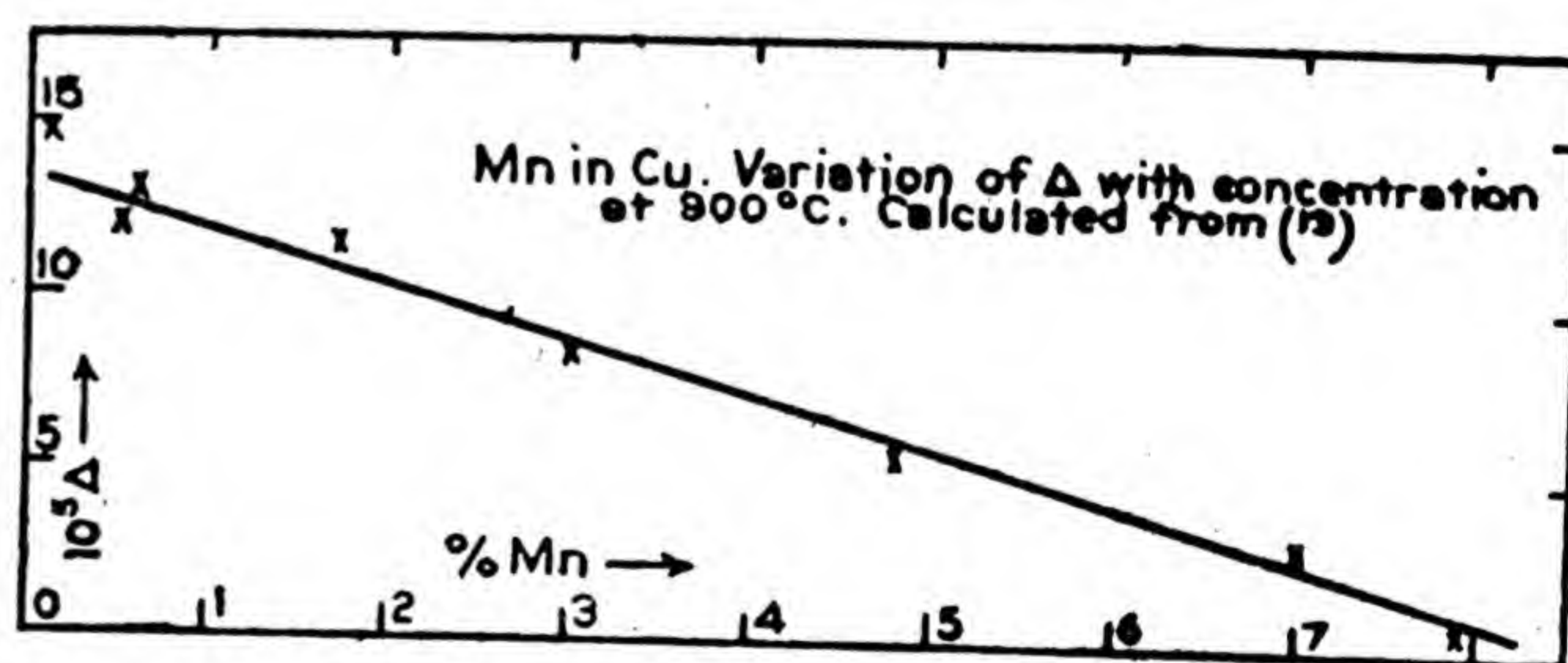
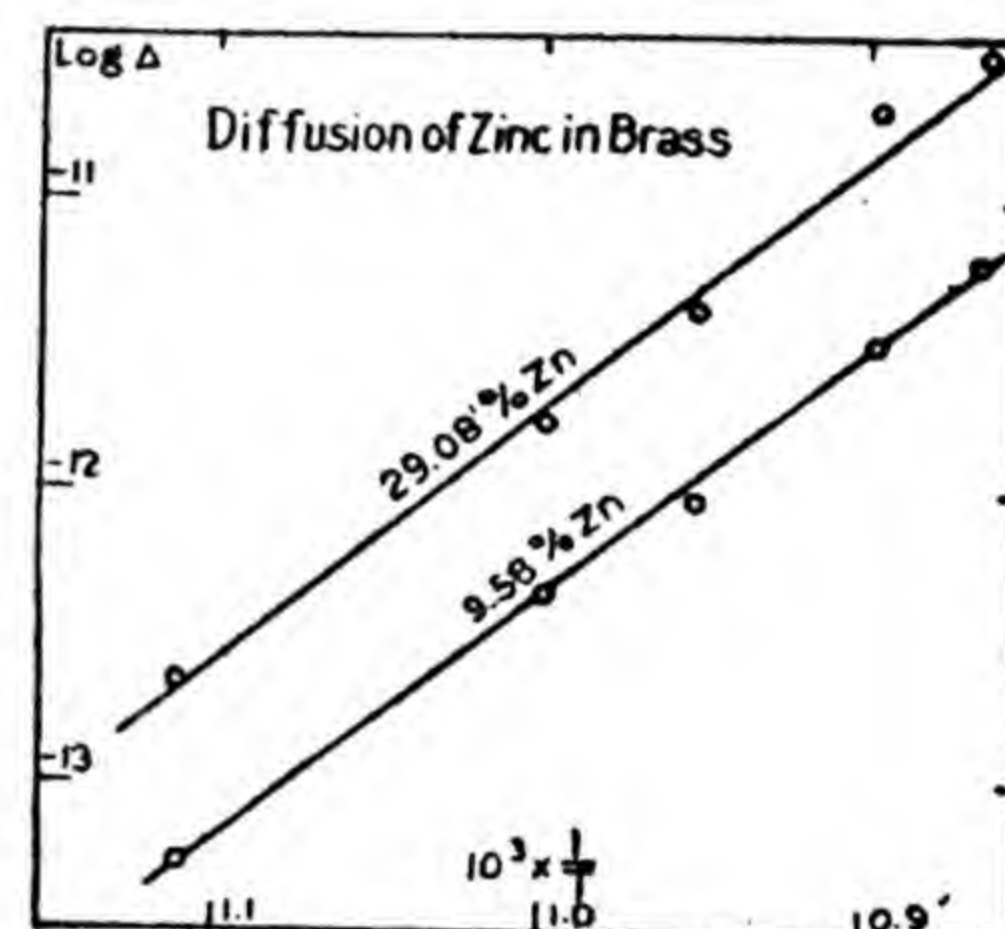
where  $x$  = velocity of diffusion in  $\text{cm}^3/\text{m}^2$  per hr;  $p$  = pressure of oxygen in mm,  $h$  = thickness of silver foil in mm, and  $T$  = abs. temp. (3).

## DIFFUSION OF ZINC IN BRASS

The values of the diffusion of zinc in  $\alpha$ -brass are shown in Fig. 1. The results may be expressed by the equation  $\Delta = Ae^{-Q/RT}$  (16).

## Discussion

The differences between the values for the diffusion of gold in silver obtained by Weiss and by Fraenkel (5, 16) on the one hand and by Braune (2) on the other may be attributed to the use of an alloy by the latter. It seems certain that the coefficient of diffusion in solids is not a constant, but falls off as the concentration of the solid solution increases. This is shown by Fig. 2. Probably a similar difference accounts for the discrepancy between the results of Tammann and those of Runge for the diffusion of carbon in  $\gamma$ -iron.



It is possible that diffusion does not occur in a single crystal of a metal unless the entering atoms are very different from those of the crystal. Hevesy and Obrutshewa (7) found no diffusion of thorium B in a single crystal of lead, the coefficient at a temperature only just below the melting point being certainly less than  $10^{-8} \text{ cm}^2/\text{day}$ . On the other hand, polonium diffused into single crystals of lead and into lead foil at about the same rate. Geiss and van Liempt (6) found no diffusion of either carbon or iron into single crystal wires of tungsten, although in the powdered condition diffusion occurred readily. Andrews and Dushman (1) determined the diffusion of carbon into tungsten wires, but did not calculate a coefficient of diffusion. They give a "coefficient



of penetration," which is not identical with it, and similar empirical coefficients are found by Weiss (16) and by Bruni and Meneghini (3) for the systems Cu-Ni, Cu-Au, and Ag-Au.

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## HEAT CAPACITY

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## MECHANICAL EQUIVALENT OF HEAT

T. H. LABY AND E. O. HERCUS

Data based upon electrical measurements have been recalculated to the basis of International ohm =  $1.00052 \times 10^9$  cgs, International ampere (defined by silver voltameter) =  $0.99997 \times 10^{-1}$  cgs, International volt (defined by ampere and ohm) =  $1.00049 \times 10^8$  cgs, Weston normal cell at 20°C =  $1.0188 \times 10^8$  cgs. Reduction to the 20°C, or the mean, calorie is by Callendar's formula (3).

$$c = 0.98536 + \frac{0.504}{t + 20} + 0.0084 \frac{t}{100} + 0.009 \left( \frac{t}{100} \right)^2$$

$c$  = specific heat in gram-calories,  $t$  = °C.

## VALUE OF 1 G CALORIE

Unit =  $10^7$  erg,  $w$  = weight assigned

Observer	w	20°C calorie	Mean calorie	Lit.
Rowland; Day*	6	4.182†		(4, 9)
Reynolds and Moorby*	2		4.1836†	(7)
Rispail*	1	4.180¶		(8)
Griffiths	2	4.1904**		(5)
Schuster and Gannon	1	4.1898††		(10)
Callendar and Barnes	3	4.1795††		(1)
Jaeger and Steinwehr	3	4.1821		(6)
Bousfield and Bousfield	1	4.1767		(2)
Henning-Sutton§§	1		4.1865	(11, 12)

Observer	w	20°C calorie	Mean calorie	Lit.
Henning-Joly§§	1		4.1877	(11, 12)
Weighted mean.....		4.1818	4.1853	
Osborne, Stimson and Flock			4.188¶¶	(13)
Laby and Hercus*		4.1809		(14)

\* Direct method.

† As given by Day.

‡ Corrected from 1 to 100° to 0 to 100°.

|| Electrical method.

¶ Reduced from 15 to 20° by Callendar's formula.

\*\* Corrected to 20°, for displaced air (10), and to Clark cell 15°C =  $1.4336 \times 10^8$  cgs.

†† Assumed presence of filter paper increased deposit by 2 in 10 000.

‡‡ Calculated on basis of King's determination of their cells =  $1.4334$  International volt =  $1.43410 \times 10^8$  cgs, and Barnes value:  $1.4335$ .

§§ Latent heat of steam.

||| Used weights assigned by Henning.

¶¶ ± 0.02 % according to the authors.

## LITERATURE

(For a key to the periodicals see end of volume)

- (1) Barnes, 5, 92: 390; 99. (2) Bousfield and Bousfield, 58, 211: 199; 11. (3) Callendar, 68, 212: 1; 12. (4) Day, 5, 46: 1; 98. (5) Griffiths, 5, 88: 23; 94. 68, 184: 361; 94. 68, 186: 261; 96. (6) Jaeger and Steinwehr, 78, 1915: 424. 8, 64: 305; 21. (7) Reynolds and Moorby, 68, 190: 301; 98. (8) Rispail, 6, 20: 417; 10. (9) Rowland, 65, 15: 75; 80. (10) Schuster and Gannon, 68, 186: 415; 95. (11) Sutton, 3, 25: 27; 18. (12) Henning, 8, 98: 759; 19. (13) Osborne, Stimson and Flock, 56, 50: 153; 28. (14) Laby and Hercus, 68, 227: 63; 27.



## THE HEAT CAPACITY OF GASES AND VAPORS

A. LEDUC

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<b>CONVERSION FACTORS</b> To convert joule $\text{g}^{-1} \text{deg}^{-1} \text{C}$ into $\text{g-cal}_{15} \text{g}^{-1} \text{deg}^{-1} \text{C}$ or into $\text{BTU}_{60} \text{lb.}^{-1} \text{deg}^{-1} \text{F}$ , multiply by 0.23895. For conversion into other units, v. Vol. I, p. 24.	<b>FACTEURS DE CONVERSION</b> Pour convertir les $C$ exprimées en joules $\text{g}^{-1} \text{deg}^{-1} \text{C}$ en $\text{cal}_{15} \text{g}^{-1} \text{deg}^{-1} \text{C}$ , ou en $\text{BTU}_{60} \text{lb.}^{-1} \text{deg}^{-1} \text{F}$ multiplier par 0,23895. Pour convertir en d'autres unités, v. Vol. I, p. 24.	<b>UMRECHNUNGSFAKTOREN</b> Um Joule $\text{g}^{-1} \text{Grad}^{-1} \text{C}$ in Gramm- $\text{cal}_{15} \text{g}^{-1} \text{Grad}^{-1} \text{C}$ umzurechnen multipliziere man mit 0,23895. Für Umrechnungen zu anderen Einheiten, siehe Bd. I, S. 24.	<b>FATTORI DI CONVERSIONE</b> Per convertire i joule $\text{g}^{-1} \text{gradi}^{-1} \text{C}$ in $\text{g-cal}_{15} \text{g}^{-1} \text{gradi}^{-1} \text{C}$ oppure in $\text{BTU}_{60} \text{lb.}^{-1} \text{gradi}^{-1} \text{F}$ bisogna moltiplicare per 0,23895. Per le conversioni in altre unità, vedi Vol. I, p. 24.	
<b>ABBREVIATIONS, SYMBOLS AND UNITS</b> $c_p$ (resp. $c_v$ ) Heat capacity per gram at constant pressure (resp. at constant volume). $C_p$ (resp. $C_v$ ) Heat capacity per gram-mole at constant pressure (resp. at constant volume). $c_m$ (resp. $C_m$ ) Mean capacity. $\delta \quad c_p - c_v$ . $\gamma \quad c_p/c_v = C_p/C_v$ . Units: Throughout this section, unless otherwise indicated, the unit of heat energy is the joule, the unit of mass, the gram (or gram-mole) and the unit of temperature, the degree centigrade.	<b>ABRÉVIATIONS, SYMBOLES ET UNITÉS</b> $c_p$ (resp. $c_v$ ) Capacité calorifique par gramme sous pression constante et à volume constant respectivement. $C_p$ (resp. $C_v$ ) Capacité calorifique par molécule-gramme sous pression constante et à volume constant respectivement. $c_m$ (resp. $C_m$ ) Capacité moyenne. $\delta \quad c_p - c_v$ . $\gamma \quad c_p/c_v = C_p/C_v$ . Unités: Dans cette section, à moins d'indication contraire, l'unité d'énergie calorifique est le joule, l'unité de masse le gramme (ou la molécule-gramme), et la température est exprimée en degrés centigrades.	<b>ABKÜRZUNGEN, ZEICHEN UND EINHEITEN</b> $c_p$ (bezw. $c_v$ ) Wärmehalt pro Gramm bei konstantem Druck (bezw. bei konstantem Volumen). $C_p$ (bezw. $C_v$ ) Wärmehalt pro Gramm-Mol bei konstantem Druck (bezw. bei konstantem Volumen). $c_m$ (bezw. $C_m$ ) Mittlere Wärmehalt. $\delta \quad c_p - c_v$ . $\gamma \quad c_p/c_v = C_p/C_v$ . Einheiten: Wenn nichts besonderes angegeben, so ist durchgehend in diesem Abschnitt die Einheit der Wärmeenergie in Joule, die Einheit der Masse in Gramm (oder Gramm-Mol) und die Temperatureinheit in Centigraden, angegeben.	<b>ABBREVIAZIONI, SIMBOLI E UNITÀ</b> $c_p$ (oppure $c_v$ ) Capacità calorifica per grammi sotto pressione costante (oppure a volume costante). $C_p$ (oppure $C_v$ ) Capacità calorifica per grammimolecola sotto pressione costante (oppure a volume costante). $c_m$ (oppure $C_m$ ) Calore specifico medio. $\delta \quad c_p - c_v$ . $\gamma \quad c_p/c_v = C_p/C_v$ . Unità: In questo capitolo, a meno che non sia altrimenti indicato, l'unità di energia calorifica è il joule, l'unità di massa, il grammo (o la grammimolecola) e l'unità di temperatura, il grado centigrado.	

## INTRODUCTION

Each of the four quantities,  $c_p$ ,  $c_v$ ,  $\delta$  and  $\gamma$ , is capable of independent experimental determination and it is sufficient to know any two in order to calculate the other two, but knowledge of a third serves as a valuable check.

The most accurate determinations of  $\gamma$  are based upon the measurement of the velocity of sound,  $V$ , and the relations:

$$V = \sqrt{\frac{E}{d}} = \frac{1}{d} \sqrt{-\gamma \frac{\partial p}{\partial v}} \quad (\text{Laplace})$$

and

$$V_{\text{obs.}} = V \left( 1 - \frac{k}{2r\sqrt{\pi N}} \right) \quad (\text{Kirchhoff})$$

where  $d$  is the density of the gas;  $v$ , the specific volume;  $V_{\text{obs.}}$ , the velocity as measured in a tube of radius  $r \geq 2.5$  cm;  $N$ , the frequency; and  $k$ , a correction factor ( $\approx 0.65$ ) which depends in an unknown manner upon the properties of the gas (e.g., upon the viscosity) and upon the nature of the tube.

The quantity  $\delta$  is computed from the thermodynamic relation

$$\delta = T \left( \frac{\partial p}{\partial T} \right)_v \left( \frac{\partial v}{\partial T} \right)_p$$

In preparing the tables in this section the values of  $\partial p/\partial T$ ,  $\partial v/\partial T$  and  $\partial p/\partial v$  required in the above equations were obtained by one (or more) of the following methods, preference being given in the order shown: (1) Accurate values based upon direct measurement; (2) values deduced from an equation of state known to correctly reproduce the observed  $p$ ,  $v$ ,  $T$  for the gas; (3) values deduced from a general equation of state obtained by the author. Method (3) was used in the majority of cases. For details, v. (29, 35).

Owing to the fact that the available data give, in many instances, opportunities for frequent cross-checks, it is not always possible to indicate, except partially, the source of all of the experimental data upon which the values given below are based. For a critique of the experimental data in this field and a discussion of the various corrections required, v. (35.5).



In all of the tables given below the quantity recorded is the total heat capacity, that is, it includes, for example, any "heat of dissociation" which may accompany the rise in temperature. Consequently a value given cannot be taken as the "true" specific heat of a molecular species unless it is known that a dissociation equilibrium is not involved.

### THE COMMON GASES AT 15°C

$p = 1 \text{ atm.}$

Gas	$C_p - C_v$	$\gamma$	$C_p$	Gas	$C_p - C_v$	$\gamma$	$C_p$
A	8.345	1.668	20.93	NO	8.353	1.400	29.25
Cl <sub>2</sub>	8.934	1.355	34.11	NH <sub>3</sub>	8.822	1.310	37.20
H <sub>2</sub>	8.316	1.410	28.58	CO	8.349	1.404	29.04
N <sub>2</sub>	8.349	1.404	29.04	CO <sub>2</sub>	8.542	1.304	36.62
O <sub>2</sub>	8.349	1.401	29.17	CN	9.081	1.256	44.57
HCl	8.609	1.41	29.59	CH <sub>4</sub>	8.387	1.31	35.45
SO <sub>2</sub>	9.136	1.29	40.64	C <sub>2</sub> H <sub>2</sub>	8.609	1.26	41.72
H <sub>2</sub> S	8.755	1.32	36.12	C <sub>2</sub> H <sub>4</sub>	8.609	1.255	42.14
N <sub>2</sub> O	8.579	1.303	36.91	C <sub>2</sub> H <sub>6</sub>	8.734	1.22	48.55

### THE COMMON GASES AT LOW TEMPERATURES

See also p. 84

$p = 1 \text{ atm. (53)}$

Gas	$t, ^\circ\text{C}$	$\gamma$	$C_p$	$C_v$	Sign of $\partial C_p / \partial t$
A	-180	1.76?	22.2	12.6	-
H <sub>2</sub>	-76	1.453	26.6	18.3	+
	-181	1.597	22.3	14.0	+
He	-180	1.660	20.9	12.6	+
N <sub>2</sub>	-181	1.47	30.0	20.4	-
O <sub>2</sub>	-76	1.415	28.7	20.3	-
	-181	1.45	30.6	21.1	-
H <sub>2</sub> S*	-45	1.30	39.8	30.7	-
	-57	1.29	41.7	32.4	-
N <sub>2</sub> O	-30	1.31	36.8	28.1	+
	-70	1.34	35.0	26.1	+
NO*	-45	1.39	30.0	21.6	-
	-80	1.38	30.7	22.2	-
CO	-180	1.41	30.3	20.6	-
CO <sub>2</sub>	-75	1.37	33.8	24.7	+
CH <sub>4</sub>	-80	1.34	33.8	25.2	+
CH <sub>4</sub> (37.9)	-74	1.35	33.4	24.8	+
	-115	1.41	30.2	21.4	+
C <sub>2</sub> H <sub>2</sub>	-71	1.31	38.2	29.1	+
C <sub>2</sub> H <sub>4</sub>	-91	1.35	36.2	26.8	+
C <sub>2</sub> H <sub>6</sub>	-82	1.28	43.7	34.1	+

\* Values doubtful.

### VALUES OF $\gamma = c_p/c_v$

#### A-TABLE, ELEMENTARY SUBSTANCES AND ATMOSPHERIC AIR

Formula	$p_{\text{atm.}}$	$t, ^\circ\text{C}$	$\gamma$	Lit.
A	1	0-100	1.67	(43)
Br	0.3-1.5	20-350	1.32	(59)
Cl	1	16	1.355	(23, 45)
	0.5	16	1.34	(23)
H <sub>2</sub> (v. p. 82)	1	17	1.407	(2.5)
	1	-21	1.420	
	1	-78	1.443	
	1	-118	1.480	
	1	-185	1.605	
Hg	0.5-1	360	1.67	(27)
I	1	185	1.30	(58)
K	1	850	1.77	(65)
	1	680-1000	1.69	(51)
Kr	1	19	1.68	(49)
Na	1	750-920	1.68	(51)
Ne	1	19	1.64	(49)

#### A-TABLE.—(Continued)

Formula	$p_{\text{atm.}}$	$t, ^\circ\text{C}$	$\gamma$	Lit.
P	1	300	1.17	(56)
Xe	1	19	1.66	(49)
Air (v. p. 81)	100	-79	2.20	(26)
	200	-79	3.33	(26)
	3	20	1.41	(54)
	1	925	1.36	(22, 58)
	1	17	1.403	(2.5)
	1	-78	1.408	
	1	-118	1.415	

#### B-TABLE, CHEMICAL COMPOUNDS

Formula	$p_{\text{atm.}}$	$t, ^\circ\text{C}$	$\gamma$	Lit.
HCl	1	100	1.40	(59)
HBr	0.3-1.5	20	1.42	(59)
HI	1	20-100	1.40	(59)
ICl	1	100	1.31	(59)
SO <sub>2</sub>	0.5	20	1.27	(54)
	2.5	20	1.35	(4, 60)
H <sub>2</sub> S	1	18	1.30	(60)
	0.5	18	1.32	(60)
N <sub>2</sub> O	1	0	1.32	(68)
	1	100	1.28	(68)
NH <sub>3</sub>	1	15	1.31	(54)
	3.5	15	1.41	(54)
CS <sub>2</sub>	satd. vap.	99.7	1.63	(28, 58)
SiCl <sub>4</sub>	0.15	14	1.13	(4)

#### C-TABLE, C-COMPOUNDS

Formula	Name	$p_{\text{atm.}}$	$t, ^\circ\text{C}$	$\gamma$	Lit.
CCl <sub>4</sub>	Carbon tetrachloride	0.1	20	1.13	(4, 62)
CHCl <sub>3</sub>	Chloroform	0.15	20	1.15	(4)
		1	100	1.15	(58)
HCN	Hydrogen cyanide	1	65	1.31	(63)
		1	140	1.28	(63)
		1	210	1.24	(63)
CH <sub>2</sub> Cl <sub>2</sub>	Dichloromethane	0.2	18	1.22	(4)
CH <sub>3</sub> Br	Methyl bromide	0.3-0.6	18	1.27	(4)
CH <sub>3</sub> Cl	Methyl chloride	0.8	16	1.28	(4)
CH <sub>3</sub> I	Methyl iodide	0.3	20	1.286	(4)
CH <sub>3</sub> O	Methyl alcohol ( $C_p = 52.3$ )	1	77	1.203	(11)
C <sub>2</sub> H <sub>5</sub> Br	Bromoethylene	0.6	15	1.20	(4)
C <sub>2</sub> H <sub>4</sub>	Ethylene	1	100	1.18	(68)
C <sub>2</sub> H <sub>4</sub> Cl <sub>2</sub>	1, 2-Dichloroethane	0.06	19	1.137	(4)
		0.2	23	1.134	(4)
C <sub>2</sub> H <sub>4</sub> O	Acetaldehyde	1	30	1.14	(68)
C <sub>2</sub> H <sub>4</sub> O <sub>2</sub>	Acetic acid	1	136	1.15	(58)
C <sub>2</sub> H <sub>5</sub> Br	Ethyl bromide	0.3	14	1.19	(4)
C <sub>2</sub> H <sub>5</sub> Cl	Ethyl chloride	0.3-0.5	16	1.19	(4)
C <sub>2</sub> H <sub>6</sub>	Ethane	1	50	1.21	(10)
		1	100	1.19	(10)
C <sub>2</sub> H <sub>6</sub> O	Ethyl alcohol ( $C_p = 78.3$ )	1	90	1.13	(11, 42)
C <sub>2</sub> H <sub>6</sub> O	Methyl ether	1	6-30	1.11	(39)
C <sub>3</sub> H <sub>5</sub> Br	Allyl bromide	0.1	15	1.145	(4)
C <sub>3</sub> H <sub>5</sub> Cl	Allyl chloride	0.2	14	1.137	(4)
C <sub>3</sub> H <sub>7</sub> O <sub>2</sub>	Methyl acetate	ca. 1	ca. 15	1.14	(4)
C <sub>3</sub> H <sub>7</sub> Br	Isopropyl bromide	0.23	12	1.13	(4)
C <sub>3</sub> H <sub>7</sub> Cl	<i>n</i> - and <i>iso</i> -Propyl chloride	0.1	21	1.13	(4)
C <sub>3</sub> H <sub>8</sub>	Propane	0.5	16	1.13	(4)
C <sub>3</sub> H <sub>8</sub> O <sub>2</sub>	Methylal	1	13	1.06	(39)
		1	40	1.09	(39)
C <sub>4</sub> H <sub>10</sub>	Isobutane	ca. 1	ca. 15	1.11	(6)



C-TABLE.—(Continued)

Formula	Name	$p_{\text{atm.}}$	$t, ^\circ\text{C}$	$\gamma$	Lit.
$\text{C}_4\text{H}_{10}\text{O}$	Ethyl ether ( $C_p = 116.3$ )	1	35	1.08	(30)
		1	80	1.086	(11, 42)
$\text{C}_6\text{H}_{12}$	Cyclohexane.....	1	80	1.08	(7)
		$C_p$	$t$	$\gamma$	Lit.
$\text{C}_5\text{H}_{12}$	<i>n</i> -Pentane.....	1 atm.	123.5	86	1.086 (11, 42)
$\text{C}_6\text{H}_6$	Benzene.....		106.3	90	1.10 (7, 11)
$\text{C}_6\text{H}_{14}$	<i>n</i> -Hexane.....		131.4	80	1.08 (11)

VALUES OF  $c_p$  AT  $t$  AND OF  $c_{p1}$  MEAN, BETWEEN  $t_1$  AND  $t_2$   
ELEMENTS AND INORGANIC COMPOUNDS

Formula	$p_{\text{atm.}}$	$t, ^\circ\text{C}$	$c_p$	Lit.
Br.....	1	83-228	0.230	(50)
	1	19-388	0.230	(59)
I.....	1	206-377	0.141	(59)
HCl.....	1	10-190	0.774	(50)
HBr.....	1	11-100	0.343	(59)
ICl.....	1	100-203	0.213	(59)
$\text{SO}_2$ .....	1	10-190	0.561	(50)
$\text{H}_2\text{S}$ .....	1	10-190	1.017	(61)
$\text{SO}_2\text{Cl}_2$ .....	1	19-98	0.477	(61.5)
$\text{N}_2\text{O}$ .....	1	25-100	0.887	(50)
	1	25-200	0.937	(50, 66)
	11	30-94	1.017	(37)
	31	30-94	1.172	(37)
NO.....	1	10-180	0.971	(50)
$\text{NO}_2$ ; <i>v. also</i> (27.5).....	1	27-67	6.78	(1.5)
	1	27-100	6.11	(1.5)
	1	27-150	4.666	(1.5)
	1	27-200	3.56	(1.5)
	1	27-300	2.68	(1.5)
$\text{PCl}_3$ .....	1	110-250	0.565	(50)
$\text{AsCl}_3$ .....	1	160-270	0.469	(50)
$\text{CCl}_4$ .....	1	0	0.586	(38)
	1	30	0.552	(38)
	1	70	0.481	(38)
$\text{CS}_2$ .....	1	80-190	0.657	(50)
	0.3	17	0.657	(60)
$\text{SiCl}_4$ .....	1	90-230	0.552	(50)
$\text{TiCl}_4$ .....	1	160-270	0.540	(50)
$\text{SnCl}_4$ .....	1	149-273	0.393	(50)

ORGANIC COMPOUNDS

Formula	Name	$p_{\text{atm.}}$	$t, ^\circ\text{C}$	$c_p$	Lit.
$\text{CHCl}_3$	Chloroform.....	1	27-118	0.607	(66)
		1	120-230	0.657	(50)
$\text{CH}_4$	Methane.....	1	10-200	2.482	(9, 50)
		11	30-94	2.620	(37)
		31	30-94	2.909	(37)
$\text{CH}_3\text{O}$	Methyl alcohol.....	1	100-223	1.917	(50)
$\text{C}_2\text{H}_4$	Ethylene.....	1	15-100	1.67	(50, 66)
		1	25-200	1.80	(66)
		11	30-94	1.76	(37)
		31	30-94	1.88	(37)
$\text{C}_2\text{H}_4\text{Cl}_2$	1, 1-Dichloroethane.....	1	110-220	0.963	(50)
$\text{C}_2\text{H}_4\text{Cl}_2$	Ethylene chloride.....	1	111-221	0.96	(50)
$\text{C}_2\text{H}_4\text{O}_2$	Acetic acid.....	1	118-140	6.28	(1.5)
		1	140-180	5.31	(1.5)
		1	180-220	3.98	(1.5)
		1	220-260	2.67	(1.5)
$\text{C}_2\text{H}_5\text{Br}$	Ethyl bromide.....	1	28-116	0.674	(66)
		1	80-200	0.795	(50)

ORGANIC COMPOUNDS.—(Continued)

Formula	Name	$p_{\text{atm.}}$	$t, ^\circ\text{C}$	$c_p$	Lit.
$\text{C}_2\text{H}_5\text{Cl}$	Ethyl chloride.....	1	10-170	1.151	(50)
		1	15-100	1.021	(20)
$\text{C}_2\text{H}_5\text{O}$	Ethyl alcohol.....	1	100-223	1.90	(50)
$\text{C}_2\text{H}_5\text{N}$	Ethyl cyanide.....	1	114-223	1.783	(50)
$\text{C}_3\text{H}_6\text{O}$	Acetone.....	1	26-10	1.452	(50)
		1	130-230	1.724	(50)
$\text{C}_4\text{H}_8\text{O}_2$	Ethyl acetate.....	1	110-220	1.678	(50)
		1	35-189	1.553	(66)
		1	35-113	1.410	(66)
$\text{C}_4\text{H}_{10}\text{O}$	Ethyl ether.....	1	35	1.862	(30)
		1	27-189	1.933	(66)
		1	69-224	2.01	(50, 55)
		1	200-300	2.231	(55)
		0.28	16	1.92	(60)
		0.28	350	2.51	(60)
$\text{C}_4\text{H}_{10}\text{S}$	Diethyl sulfide.....	1	120-223	1.67	(50)
$\text{C}_6\text{H}_{10}$	Amylene.....		ca. 210	2.64	(14)
$\text{C}_5\text{H}_{12}$	Isopentane.....	1	58	1.88	(64)
		1	100	1.97	(8)
$\text{C}_6\text{H}_6$	Benzene.....	1	80	1.09	(30)
		1	34-115	1.26	(66)
		1	35-180	1.39	(66)
		1	100	1.39	(7)
		1	120-220	1.55	(50)
$\text{C}_6\text{H}_{12}$	Cyclohexane.....	1	100	1.73	(7)
$\text{C}_{10}\text{H}_{16}$	Terebenthene.....	1	180-250	2.12	(50)

## SPECIAL TABLES

## Atmospheric Air

## EFFECT OF TEMPERATURE

 $p = 1 \text{ atm. (2, 9, 16, 46, 48)}$ 

$t, ^\circ\text{C}$	$c_p - c_v$	$\gamma$	$c_p$	$c_m, 0 \text{ to } t^\circ$
0	0.2883	1.403	1.004	1.004
100	0.2882	1.401	1.006	1.005
200	0.2875	1.398	1.010	1.009
400	0.2871	1.393	1.017	1.013
600	0.2871	1.385	1.034	1.017
800	0.2871	1.376	1.055	1.025
1000	0.2871	1.365	1.076	1.034
1200	0.2871	1.353	1.101	1.042
1400	0.2871	1.341	1.130	1.050
1600	0.2871	1.329	1.160	1.063
1800	0.2871	1.316	1.193	1.076
2000	0.2871	1.303	1.234	1.088

## EFFECT OF PRESSURE

Values of  $c_p$  above  $0^\circ$  (52)

$p_{\text{atm.}}$	$0^\circ$	$50^\circ$	$100^\circ$	$150^\circ$	$200^\circ$	$280^\circ$
20	1.042	1.038	1.034	1.034	1.030	1.034
60	1.113	1.088	1.071	1.059	1.050	1.042
100	1.172	1.138	1.088	1.088	1.076	1.055
140		1.180	1.138	1.113	1.092	1.063
180		1.214	1.168	1.134	1.109	1.076
220		1.239	1.189	1.151	1.122	1.084

Values of  $c_p$  below  $0^\circ$  (67)

$p_{\text{atm.}}$	$-50^\circ$	$-100^\circ$	$-120^\circ$	$-140^\circ$
10	1.021	1.080	1.138	1.707
20	1.055	1.184	1.348	2.678
40	1.147	1.400	2.005	10.91
70	1.306	1.925	3.252	
1		$-78^\circ$ 1.017	$-185^\circ$ 1.055	Lit. (53)



## Atmospheric Air.—(Continued)

VALUES OF  $\gamma$ 

$p_{\text{atm.}}$	0°		-79.4°	
	(26)	(67)	(26)	(67)
25	1.47	1.47	1.57	1.58
50	1.53	1.53	1.77	1.79
75	1.59	1.58	2.00	2.06
100	1.65	1.64	2.20	2.30
125	1.69		2.40	
150	1.74		2.47 max.	
175	1.78		2.41	
200	1.83		2.33	

VALUES  $c_v$ , MEAN, 15-100° (21)

$d, \text{g/cm}^3$ .....	0.01	0.03	$p = 1 \text{ atm.}$
$c_v$ .....	0.719	0.721	0.717

 $\text{H}_2$ , Hydrogen; cf. (69)

$t, ^\circ\text{C}$ (5, 48, 57)	$C_p$	$\gamma$	$C_m$ , 0 - $t^\circ$	$t, ^\circ\text{K}$ (12)	$C_v$
0	28.58	1.410	28.58	35	12.47
100	28.92	1.404	28.75	50	12.60
200	29.21	1.398	28.92	65	12.72
400	29.80	1.387	29.21	80	13.14
600	30.38	1.377	29.50	90	13.64
800	30.97	1.367	29.80	100	14.31
1000	31.55	1.358	30.09	110	15.15
1200	32.14	1.349	30.38	196.5	18.37
1400	32.73	1.341	30.68	273.1	20.26
1600	33.31	1.333	30.97		
1800	33.90	1.325	31.26		
2000	34.48	1.318	31.55		

 $\text{O}_2$ ,  $\text{N}_2$  and CO

For best values at 0°, v. p. 81; see also Fig. 2. The following values are from Partington and Shilling (47):

$t^\circ, \text{C}$	$C_p - C_v$	$\gamma$	$C_p$	$C_m$ , 0 to $t^\circ$
0	8.362	1.402	29.17	29.17
100	8.332	1.399	29.21	29.19
200	8.324	1.396	29.29	29.23
400	8.324	1.391	29.63	29.34
600	8.320	1.383	30.01	29.50
800	8.320	1.375	30.51	29.67
1000	8.316	1.365	31.14	29.92
1200	8.316	1.353	31.85	30.17
1400	8.316	1.342	32.64	30.47
1600	8.316	1.329	33.56	30.80
1800	8.316	1.316	34.61	31.18
2000	8.316	1.303	35.74	31.55

For  $\text{N}_2$  {  $C_p = 6.815 + 3.17 \times 10^{-4}t + 5.3 \times 10^{-8}t^2$  g-cal<sub>18</sub>/mole.  
 $C_v = 4.82 + 3.3 \times 10^{-4}t + 4.7 \times 10^{-8}t^2$  g-cal<sub>18</sub>/mole.  
 For  $\text{O}_2$  {  $C_p = 6.98 + 1.88 \times 10^{-4}t + 6.7 \times 10^{-8}t^2$  g-cal<sub>18</sub>/mole.  
 $C_v = 4.98 + 2.1 \times 10^{-4}t + 5.5 \times 10^{-8}t^2$  g-cal<sub>18</sub>/mole.

 $\text{H}_2\text{O}$ VARIATION OF  $c_p$  WITH TEMPERATURE AND PRESSURE (17, 25)

$t, ^\circ\text{C}$	1 atm.	2 atm.	4 atm.	6 atm.	10 atm.	14 atm.	20 atm.
100	2.017						
120	1.996	2.093					
140	1.984	2.046					
160	1.975	2.021	2.155	2.356			
180	1.971	2.005	2.101	2.226	2.645		
200	1.971	1.996	2.067	2.151	2.381	2.808	
250	1.980	1.996	2.034	2.072	2.155	2.264	2.461
300	1.996	2.009	2.034	2.059	2.109	2.159	2.247

 $\text{H}_2\text{O}$ —(Continued)VARIATION OF  $c_p$  WITH TEMPERATURE AND PRESSURE.—(Cont'd)

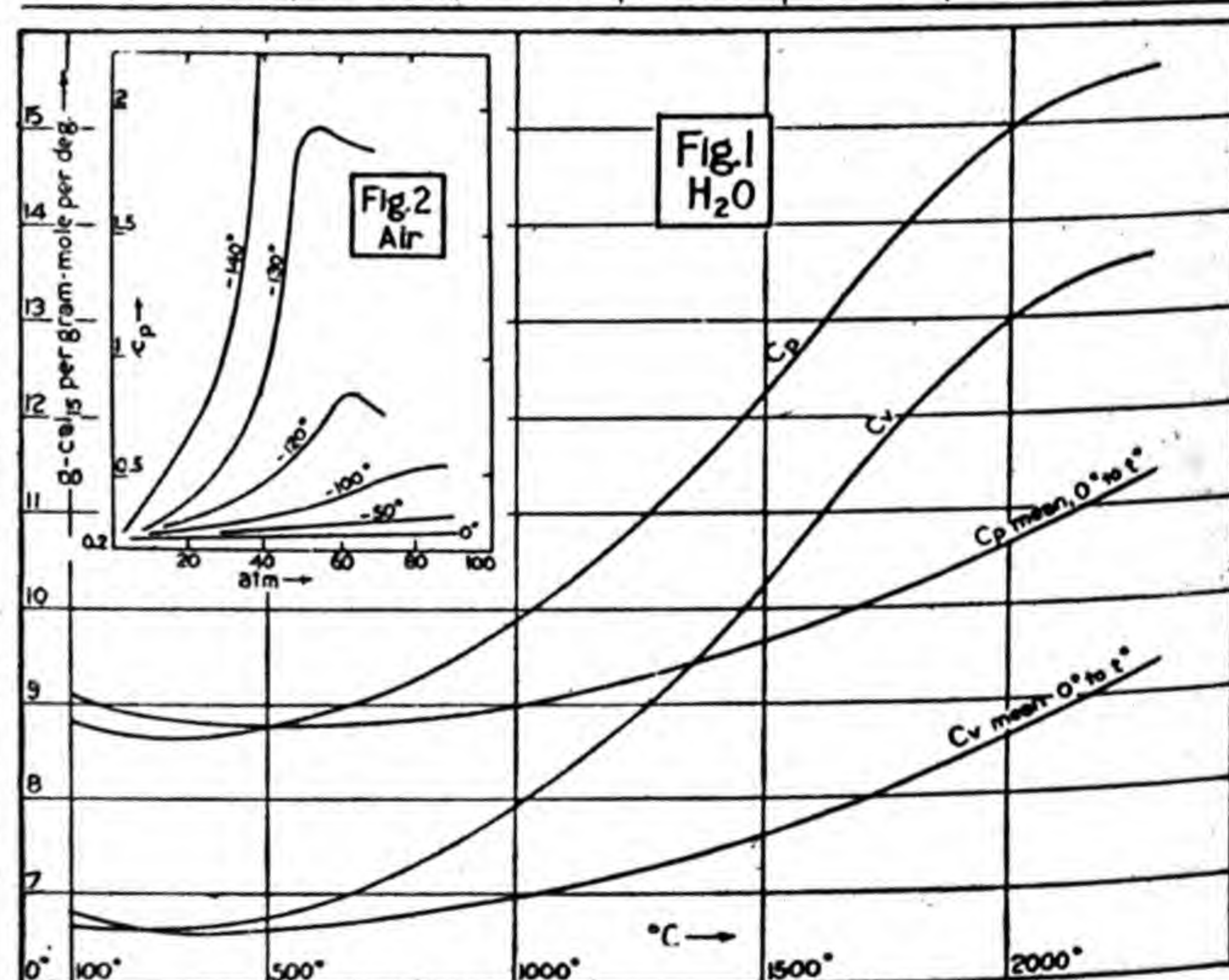
$t, ^\circ\text{C}$	1 atm.	2 atm.	4 atm.	6 atm.	10 atm.	14 atm.	20 atm.
350	2.021	2.025	2.051	2.068	2.103	2.141	2.214
400	2.051	2.059	2.076	2.093	2.122	2.155	2.205
450	2.084	2.093	2.113	2.118	2.139	2.164	2.201
500	2.122	2.126	2.134	2.143	2.159	2.176	2.201
550	2.156	2.159	2.164	2.168	2.180	2.189	2.210

VARIATION OF  $c_p$  WITH TEMPERATURE FOR  $p = 1 \text{ ATM.}$  (15)

$t, ^\circ\text{C}$ .....	200	400	600	800	1000	1200	1400
$c_p$ .....	1.946 extrap.	1.980	2.055	2.172	2.335	2.544	2.796

"BEST" VALUES FOR  $p = 1 \text{ ATM.}$  (47)

$t, ^\circ\text{C}$	$C_p - C_v$	$\gamma$	$C_v$	$t, ^\circ\text{C}$	$C_p - C_v$	$\gamma$	$C_v$
100	8.927	1.324	27.54	1000	8.328	1.252	33.06
200	8.550	1.310	27.58	1200	8.324	1.229	36.41
300	8.424	1.304	27.66	1400	8.320	1.206	40.47
400	8.378	1.301	27.83	1600	8.320	1.182	45.32
500	8.357	1.296	28.21	1800	8.320	1.163	42.56
600	8.345	1.290	28.80	2000	8.320	1.155	54.20
700	8.337	1.282	29.55	2200	8.320	1.148	56.29
800	8.332	1.273	30.55	2300	8.320	1.146	56.79
900	8.328	1.263	31.68				

MEAN  $C_p$  BETWEEN 100 AND  $t^\circ$  (40)

$t, ^\circ\text{C}$ .....	1000	1250	1500	1750	2000	2250	2500	3000
$C_p$ , 100- $t^\circ$ .....	28.96	30.13	31.39	33.06	35.24	37.62	40.00	45.41

 $c_p$  FOR SLIGHTLY UNDER-SATURATED VAPOR<sup>1</sup> (17)

$t, ^\circ\text{C}$ .....	99.1	119.6	142.9	169.6	187.1	200.5	211.4
$p$ , kg/cm <sup>2</sup> .....	1	2	4	8	12	16	20
$c_p$ .....	2.017	2.088	2.231	2.511	2.817	3.135	3.490

\* These values are not in agreement with those calculated thermodynamically from the temperature coefficient of the latent heat.

## "BEST" VALUES FOR THE SATURATED VAPOR

$t, ^\circ\text{C}$	$c_p$	$c_v$	$\gamma$
100	1.816	1.318	1.373*
120	1.871	1.356	1.378
140	1.971	1.422	1.380

\* This is consistent with Neyreneuf's value of the velocity of sound (42).

## "BEST" VALUES FOR THE SUPERHEATED VAPOR

$p$ , atm.	$t, ^\circ\text{C}$	100	120	140	150	160
1	$c_p$	1.816	1.833	1.875	1.93	2.005
	$\gamma$		1.365	1.346	1.333	1.314



**H<sub>2</sub>O.—(Continued)****"BEST" VALUES FOR THE SUPERHEATED VAPOR.—(Cont'd)**

<i>p</i> , atm.	<i>t</i> , °C	100	120	140	150	160
2	<i>c<sub>p</sub></i>		1.871	1.913	1.959	2.026
	<i>γ</i>		1.37*	1.36	1.344	1.326
3	<i>c<sub>p</sub></i>			1.959		
	<i>γ</i>			1.37	1.356	1.34
4	<i>c<sub>p</sub></i>				2.026	2.076
	<i>γ</i>				1.37	1.35

\* At 130°

**NH<sub>3</sub>**VARIATION OF *c<sub>p</sub>* WITH TEMPERATURE AND PRESSURE (44)

<i>t</i> , °C	<i>p</i> <sub>atm.</sub>	0	1	2	4	8	12	16	20
Satd.		2.340	2.483	2.701	3.030	3.300	3.561	3.843	
-30		2.020	2.306						
-10		2.043	2.195	2.386					
0		2.057	2.173	2.314	2.657				
+20		2.085	2.159	2.244	2.446	2.988			
40		2.116	2.167	2.252	2.350	2.665	3.078		
60		2.149	2.186	2.226	2.313	2.515	2.759	3.058	3.448
80		2.184	2.212	2.242	2.305	2.445	2.605	2.789	3.008
100		2.220	2.214	2.265	2.312	2.415	2.528	2.652	2.792
120		2.256	2.274	2.293	2.330	2.409	2.492	2.582	2.679
150		2.294	2.327	2.340	2.368	2.422	2.481	2.540	2.603

VALUES OF *c<sub>p</sub>* AT HIGH TEMPERATURES

Mean of (13 and 41) ± 10 %

<i>t</i>	309°	422°	523°
<i>C<sub>p</sub></i> .....	41.4	43.9	47.08
<i>c<sub>p</sub></i> .....	2.43	2.59	2.76

Nernst (41) gives  $C_p = 8.62 + 0.002t + 7.2 \times 10^{-6}t^2$ , g-cal<sub>18</sub>/mole. Range 0 to 680°.For very high temperatures Budde (3) gives the equation  $C_p = 11.8 + 0.024 \times (t - 1400)$ , g-cal<sub>18</sub>/mole. This gives 11.8 at 1400° and 21.4 at 2200°.**CO<sub>2</sub>, v. p. 86****CO<sub>2</sub>**EFFECT OF TEMPERATURE AT *p* = 1 ATM. (2, 11, 15, 48) $C_p = 6.63 + 5.54 \times 10^{-4}t - 2.47 \times 10^{-6}t^2 + 4.7 \times 10^{-10}t^3$ , g-cal<sub>18</sub>/mole (53)

<i>t</i> , °C	<i>C<sub>p</sub></i> - <i>C<sub>v</sub></i>	<i>γ</i>	<i>C<sub>p</sub></i>	<i>C<sub>m</sub></i> , 0- <i>t</i> °
0	8.600	1.310	36.33	36.33
100	8.429	1.281	38.38	37.37
200	8.374	1.263	40.18	38.25
300	8.349	1.247	42.18	39.09
400	8.337	1.235	43.82	39.92
500	8.328	1.225	45.24	40.76
600	8.324	1.217	46.60	41.43
700	8.324	1.210	47.86	42.27
800	8.320	1.204	49.01	42.98
900	8.320	1.200	50.01	43.69
1000	8.320	1.195	50.89	44.24
1100	8.320	1.192	51.68	44.78
1200	8.314	1.189	52.40	45.24
1300	8.314	1.186	53.02	45.73
1400	8.314	1.184	53.61	46.24
1500	8.314	1.181	54.20	46.75
1600	8.314	1.179	54.74	47.21
1700	8.314	1.177	55.28	47.75
1800	8.314	1.175	55.83	48.25
1900	8.314	1.173	56.33	48.76
2000	8.314	1.171	56.92	49.26

Between -75 and +20°,  $C_p = 8.71 + 66 \times 10^{-4}t - 22 \times 10^{-7}t^2$  g-cal/mole (15).**CO<sub>2</sub>—(Continued)**VARIATION OF *c<sub>p</sub>* WITH PRESSURE,  $\frac{\partial c_p}{\partial p} > 0$ ,  $\frac{\partial c_p}{\partial T} < 0$  (37.2)For data near the critical point, *v*. (1)

<i>p</i> <sub>atm.</sub>	13.2°	38°	67.6°	98.1°	114.9°
24.25		1.205	1.030		
54.1	3.06	1.364	1.151		
61.7	3.72	1.833	1.352	1.327	1.310
68.2	4.70	2.369			
75.8	6.16	3.059	2.026	1.93	1.611
85.4	8.83	4.164		2.498	2.226
86.9			2.691		

<i>p</i> <sub>atm.</sub> (19)	-10°	0°	+10°	20°	30°
20.5	1.201	1.159	1.117	1.071	1.030
27.3		1.381	1.289	1.193	1.058

VARIATION OF *c<sub>v</sub>* WITH *t* AND *d* (21)

	<i>d</i> = 0.124 g/cm <sup>3</sup>			<i>d</i> = 0.18 g/cm <sup>3</sup>	
<i>t</i> , °C.....	10	50	100	50	100
<i>c<sub>v</sub></i> .....	0.933	0.824	0.795	0.866	0.862
<i>d</i> , g/cm <sup>3</sup> .....		0.0387	0.077	0.118	0.144
<i>c<sub>m</sub></i> , 12-100°.....		0.7173	0.7700	0.8119	0.8457

 $c_v = 0.165 + 0.02125d + 0.340d^2$ , g-cal<sub>18</sub>/g.**CH<sub>4</sub>, Methane (9)**

<i>t</i> , °C	<i>C<sub>p</sub></i> - <i>C<sub>v</sub></i>	<i>γ</i>	<i>C<sub>p</sub></i>	<i>C<sub>m</sub></i> , 0- <i>t</i> °
0	8.403	1.307	35.78	35.78
100	8.353	1.232	44.36	40.05
200	8.337	1.188	52.61	44.36
300	8.328	1.160	60.47	48.42
400	8.324	1.139	68.01	52.40
500	8.324	1.125	75.12	56.25
600	8.320	1.113	81.90	59.97

**CH<sub>3</sub>Cl and C<sub>2</sub>H<sub>5</sub>Cl (20, 56)**VARIATION OF *c<sub>p</sub>* WITH *t* AND *p*

<i>t</i>	<i>C<sub>2</sub>H<sub>5</sub>Cl</i>			<i>p</i> <sub>atm.</sub>	<i>CH<sub>3</sub>Cl</i>			
	0.137	1.37	2.74		0.68	2.72	5.46	8.2
-30	0.88			-30	0.84			
0	0.92			0	0.88			
+40	1.00	1.02	1.03	+30	0.90	0.93	0.96	1.01
80	1.06	1.09	1.13	70	0.95	0.96	1.00	1.04
110		1.13	1.17	110	0.97	1.00	1.03	1.07

**SATURATED VAPORS**Values of *c<sub>s</sub>*, the heat required to heat the vapor through 1°C and maintain it in the saturated condition, joule per g/deg C.

	<i>H<sub>2</sub>O</i>			<i>(C<sub>2</sub>H<sub>5</sub>)<sub>2</sub>O</i>	
<i>t</i> , °C.....	58	93	148	0	120
<i>c<sub>s</sub></i> .....	-5.9	-5.0	-0.33	0.485	0.557

	<i>C<sub>6</sub>H<sub>6</sub>, Benzene</i>			<i>H<sub>2</sub></i>	
<i>t</i> , °C.....	0	120	210	-257.24	-252.7
<i>c<sub>s</sub></i> .....	-7.34	0	0.48	-23.2	-15.8

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(For a key to the periodicals see end of volume)

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THERMODYNAMIC QUANTITIES: VALUES OF THE HEAT CAPACITY, ENTROPY, HEAT CONTENT AND "THERMODYNAMIC POTENTIAL" FOR PURE SUBSTANCES BETWEEN 0 AND 298°K

W. H. RODEBUSH AND ESTHER RODEBUSH

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INTRODUCTION	INTRODUCTION	EINLEITUNG	INTRODUZIONE	
Unless otherwise indicated, the values given in this section apply in all cases to the form which is stable under 1 atm. pressure at the temperature in question.	À moins d'une autre indication, les valeurs données dans cette section se rapportent dans tous les cas à la forme qui est stable sous une pression d'une atmosphère à la température en question. Dans tous les cas, l'unité de masse est le poids moléculaire, l'unité d'énergie est le joule, et l'unité de température est le degré K. La pression est 1 atmosphère.	Wenn nichts anderes angegeben, so beziehen sich die gegebenen Werte dieses Abschnittes in allen Fällen auf die bei 1 Atm. und der fraglichen Temperatur, stabile Form.	I valori riportati in questo capitolo si riferiscono (a meno che non sia altrimenti indicato) alla forma stabile a pressione atmosferica e alla temperatura in questione.	
In all cases, the mass unit is the gram-formula-weight, the energy unit is the joule, and the temperature unit is °K. The pressure is 1 atmosphere.	Dans tous les cas, la valeur concernant chaque quantité mentionnée est supposée être 0 à 0°K.	In allen Fällen ist die Mengeneinheit das Grammformelgewicht, die Einheit der Energie ist Joule und die für die Temperatur ist °K. Der Druck ist 1 Atmosphäre.	In tutti i casi l'unità di massa è la grammimolecola, l'unità di energia il joule e l'unità di temperatura il °K. La pressione è 1 atmosfera.	
In all cases, the value of each of the quantities tabulated is assumed to be 0 at 0°K.	Le nombre d'unités incertaines à une place donnée des chiffres significatifs est indiqué par le nombre de barres se trouvant sur le chiffre à cette place, une barre indiquant ± 1 à 3 unités, deux barres, ± > 3 unités.	In allen Fällen wird angenommen, dass jede Grösse, welche in der Tabelle angegeben ist, bei 0°K selbst Null ist.	In tutti i casi il valore delle quantità riportate nella tabella è supposto essere 0 a 0°K.	
The number of units uncertain in a given place of significant figures is indicated by the number of bars over the figure in that place, one bar indicating ± 1 to 3 units, two bars, ± > 3 units.		Die Zahl der Einheiten die an einer gegebenen Stelle einer gewerteten Zahl unsicher sind, werden durch die Anzahl von Strichen über der Zahl an dieser Stelle angezeigt. Ein Strich bedeutet ± 1 bis 3 Einheiten, zwei Striche ± mehr wie 3 Einheiten.	Le unità di cui è incerto un determinato numero significativo, sono indicate dal numero di linee stampate sopra la cifra stessa. Una linea indica ± da 1 a 3 unità, due linee ± > 3 unità.	
C <sub>p</sub> Heat capacity per gram-formula-weight.	C <sub>p</sub> Capacité calorifique par molécule gramme.	C <sub>p</sub> Wärmekapazität pro Grammformelgewicht.	C <sub>p</sub> Calore specifico per un peso in grammi corrispondente alla formula.	
S Entropy.	S Entropie.	S Entropie.	S Entropia.	
H Heat content. Computed from heats of formation in the case of compounds.	H Chaleur totale. Calculée à partir des chaleurs de formation dans le cas des composés.	H Wärmeinhalt. Berechnet aus der Bildungswärme im Falle einer Verbindung.	H Capacità termica. Computata, nel caso di composti, dai calori di formazione.	



# HEAT CAPACITY OF ELEMENTARY SUBSTANCES BETWEEN 0 AND 300°K

DEWAR'S VALUES OF MEAN ATOMIC HEAT CAPACITY BETWEEN  
77.4 AND 20.35°K (3)  
Joules per gram-atom per °C

As, 7.57	Cl, 13.40	Mn, 4.94	Rh, 5.4
Au, 12.4	Co, 4.77	Mo, 5.37	Ru, 4.35
B, 0.94	Cr, 2.76	Ni, 4.77	Se, 11.19
Ba, 18.8	Cs, 26.7	Os, 5.82	Sr, 18.84
Be, 0.49	"Di," 18.14	Pd, 7.95	Te, 14.4
Bi, 17.75	Ir, 7.53	P(r), 5.23	Th, 17.95
Br, 14.15	La, 18.0	P(y), 9.37	Ti, 3.84
Ce, 18.18	Li, 5.27	Pt, 10.3	U, 12.9
		Rb, 23.65	Zr, 9.33

## A-TABLE.—ELEMENTARY SUBSTANCES

Molecular heat capacity, joules per gram-formula-weight per °C

Argon		C, Graphite (19)		Cd.—(Cont'd)	
T, °K	C <sub>p</sub>	T, °K	C <sub>p</sub>	T, °K	C <sub>p</sub>
Solid (6)		20	0.1	100	22.25
15	6.3	30	0.25	150	24.2
21	14.7	40	0.4	200	25.15
30	18.8	50	0.6	250	25.75
36	22.8	60	0.75	300	26.2
45	24.7	70	1.0	Cl <sub>2</sub> , Solid (7)	
60	27.6	80	1.15	22	10.0
75	31.4	90	1.40	30	17.6
Liquid (6)		100	1.6	35	21.8
84 to 88	44.0	150	3.2	40	26.4
Gas (12)		200	5.0	45	29.7
90	22.2	250	6.85	52	32.7
100	22.2	300	8.6	80	39.8
150	22.0	C, Diamond (20)		90	41.5
200	21.7	90	0.04	100	43.1
250	21.4	100	.25	110	44.7
300	21.1	125	.8	150	53.6
Ag (9, 19, 20)		150	1.4	155	54.8
20	1.7	175	2.0	Cl <sub>2</sub> , Liquid (7)	
30	4.35	200	2.5	188 to 197	68.0
40	8.05	250	4.2	Co, v. p. 93	
50	11.1	300	6.25	Cu (9, 14, 20)	
60	13.9	Ca (4, 10)		20	0.4
70	15.9	10	0.75	30	1.7
80	17.6	20	2.1	40	3.4
90	19.0	30	4.0	50	5.86
100	20.05	40	7.15	60	8.1
150	23.15	50	10.25	70	10.4
200	24.25	60	13.1	80	12.5
250	24.95	70	15.5	90	14.6
300	25.35	80	17.8	100	16.3
Al (9, 20, 21)		90	19.1	150	21.0
20	0.3	100	20.4	200	22.7
30	1.1	150	24.0	250	23.7
40	2.2	200	25.35	300	24.6
50	3.90	250	25.65	Fe (9)	
60	5.85	300	25.9	30	0.6
70	7.75	Cd (9, 25)		40	2.2
80	9.45	20	3.2	50	4.15
90	11.2	30	6.9	60	6.1
100	12.9	40	11.2	70	7.8
150	18.5	50	15.0	80	9.55
200	21.65	60	17.5	90	11.2
250	23.2	70	19.35	100	12.9
300	24.5	80	30.65	150	18.8
		90	21.6	K (4)	
				10	6.07

Fe.—(Cont'd)		K.—(Cont'd)	
T, °K	C <sub>p</sub>	T, °K	C <sub>p</sub>
200	21.8	60	22.05
250	23.8	70	23.75
300	25.2	80	24.6
He (2.5)		90	25.1
H <sub>2</sub> , Solid (16, 31)		100	25.35
12	4.18	150	26.6
H <sub>2</sub> , Liquid (6, 16, 31)		200	27.8
15 to 21	1.38 + 0.860T	250	29.0
H <sub>2</sub> , Gas (5)		300	30.2
30	20.8	Mg (4, 21)	
40	20.8	20	0.50
50	20.8	30	1.85
60	20.8	40	3.60
70	21.1	50	6.15
80	21.6	60	8.6
90	22.2	70	10.95
100	22.8	80	13.15
150	25.3	90	15.1
200	26.8	100	16.6
250	28.0	150	21.45
300	29.1	200	23.35
Hg, Solid		250	24.4
(1, 22, 24, 28, 29)		300	25.25
10	4.8	N <sub>2</sub> , Solid (6, 15)	
20	10.0	N <sub>I</sub>	
30	15.7	15	12.5
40	18.8	21	25.1
50	20.9	30	30.5
60	22.2	N <sub>II</sub>	
70	23.0	45	39.7
80	23.9	51	42.3
90	24.1	60	45.2
100	24.5	N <sub>2</sub> , Liquid (6, 15)	
150	26.0	64 to 76	55.6
200	27.2	N <sub>2</sub> , Gas (27)	
Hg, Liquid (33)		80	30.2
235 to 298	28.0	90	30.2
1/2 I <sub>2</sub> , Solid (17)		100	30.1
15	4.6	150	29.9
21	9.85	200	29.7
30	12.8	250	29.5
36	15.7	300	29.1
45	17.6	Na (9, 11, 30)	
60	20.1	20	2.5
75	21.8	30	5.25
90	22.9	40	9.1
105	23.4	50	13.4
120	23.8	60	16.75
135	24.1	70	18.95
150	24.5	80	20.6
180	25.1	90	21.55
200	25.6	100	22.25
250	26.8	150	24.8
300	27.8	200	26.3
O <sub>2</sub> , Solid (6)		250	27.4
10	6.07	300	28.55
20	11.0	O <sub>I</sub>	
30	15.2	15	9.20
40	18.35	18	11.25
50	20.8	21	16.7

O <sub>2</sub> , Solid.—(Cont'd)		O <sub>2</sub> , Liquid (6)	
T, °K	C <sub>p</sub>	57 to 73	53.2
O <sub>II</sub>		O <sub>2</sub> , Gas (27)	
30	27.9	90	32.6
36	36.8	100	32.4
39	41.8	150	29.4
O <sub>III</sub>		200	29.7
46	45.2	250	28.4
Pb (8, 9, 13, 19)		300	29.4
20	11.1	Pd, v. p. 93	
30	16.65	S, Rhombic (19)	
40	19.9	10	1.3
50	22.0	20	3.0
60	22.75	30	4.8
70	23.4	40	6.15
80	23.9	50	7.4
90	24.2	60	8.7
100	24.45	70	9.95
150	25.1	80	11.2
200	25.45	90	12.3
250	25.9	100	13.4
300	26.4	150	17.2
S, Monoclinic (19)		200	19.6
83	11.55	250	21.45
87	12.15	300	23.3
91	12.4	Sb (11)	
97	12.45	80.4	21.7
102	13.2	81.6	21.2
194	20.6	83.7	21.1
200	20.95	85.6	21.8
		86.2	21.8
		92.0	22.3
		93.3	22.4
		98.1	22.9



**TABLE.—CHEMICAL COMPOUNDS; *v. also* p. 89.**  
Standard Arrangement (*v. Vol. III, p. viii*)

19.9	4.96	90.6	42.1
23.4	6.74	100.6	46.3
26.9	8.78	102.1	46.3
31.4	11.71	105.4	48.1
36.0	14.36	114.1	51.1
39.2	16.3	130.9	58.4
44.2	18.16	153.7	67.6
48.8	21.75	158.0	69.6
51.8	23.5	200.1	86.9
56.0	25.9	202.5	88.7
60.9	28.8	231.5	101.8
66.5	31.4	251.9	110.0
69.8	32.6	269.9	119.5
79.2	37.0	287.2	126.2
84.6	39.6	296.2	135.0



**PbI<sub>2</sub> (21)**

<i>T</i> , °K	<i>C<sub>p</sub></i>	<i>T</i> , °K	<i>C<sub>p</sub></i>
22.3	29.5	89.4	71.5
26.2	32.85	95.6	72.3
38.2	44.9	235.0	784.0
50.6	55.2	332.0	823.0
62.1	61.8		

**Hg<sub>2</sub>SO<sub>4</sub> (24)**

23.5	25.2	76.6	68.2
26.5	34.2	85.0	71.5
30.0	39.4	201.0	108.9
56.2	58.9	290.0	129.2

**BeO (10)**

76.8	0.85	79.7	1.02
78.1	.92	80.3	0.93
78.6	.82	82.6	0.99
79.3	.95	84.9	1.15

**Ca(OH)<sub>2</sub> (21)**

21.4	2.06	47.4	6.96
26.3	2.94	50.4	9.63
31.4	3.42	53.8	12.34
37.6	4.54	76.2	16.95
40.7	5.38	86.0	21.3

**CaH<sub>2</sub> (10)**

69.9	7.5	80.1	9.92
71.2	7.78	80.9	9.92
72.5	7.95	86.2	11.48
79.0	9.42		

**CaCO<sub>3</sub>, Aragonite (10)**

23.3	0.97	38.6	4.05
26.8	1.16	41.7	5.34
29.7	1.53	47.7	7.7
31.9	2.18	50.5	9.3
34.1	2.86	52.6	10.42
35.9	3.54	56.2	10.85

**Al<sub>2</sub>(SO<sub>4</sub>)<sub>3</sub>·K<sub>2</sub>SO<sub>4</sub>·24H<sub>2</sub>O (21)**

25.7	116.5	41.7	252.3
28.3	136.1	46.0	302.5
30.0	144.2	50.6	350.0
31.2	158.8	54.0	368.5
32.8	175.5	71.9	503.0
34.7	181.8	84.4	592.0
36.0	210.0	90.5	693.0

**ENTROPY, HEAT CONTENT AND THERMODYNAMIC POTENTIAL****A-TABLE.—ELEMENTARY SUBSTANCES****Argon (6, 12)**

<i>T</i> , °K	<i>C<sub>p</sub></i>	<i>S</i>	<i>H</i>	<i>F</i> = <i>H</i> - <i>TS</i>
0	0	0	0	0
50	25.85	23.4	712	- 468
100	22.4	130.4	3 035	-10 005
150	21.75	139.4	4 145	-16 735
200	21.55	145.6	5 240	-22 860
250	21.35	150.4	6 320	-31 280
273.1	21.30	152.0	6 800	-34 700
298.1	21.23	154.0	7 340	-38 560

**Ag (9, 19, 20)**

50	11.3	5.91	192	- 103
100	20.2	17.2	1 012	- 708
150	23.2	26.0	2 095	- 1 805
200	24.4	32.8	3 280	- 3 280
250	25.0	38.3	4 520	- 5 060
273.1	25.2	40.5	5 100	- 5 970
298.1	25.3	42.7	5 730	- 6 990

**Al (9, 20, 21)**

0	0	0	0	0
50	3.75	1.23	52.1	- 9.4
100	13.1	6.82	465.0	- 217
150	18.63	13.22	1 272	- 710
200	21.55	18.98	2 285	- 1 505
250	23.23	23.95	3 500	- 2 480
273.1	23.85	26.1	4 040	- 3 080
298.1	24.4	28.15	4 630	- 3 750

**C, Graphite (19)**

0	0	0	0	0
50	0.54	0.29	11.9	- 2.8
100	1.72	1.04	73.3	- 31
150	3.26	1.97	189	- 107
200	5.10	3.18	394	- 242
250	6.94	4.44	688	- 422
273.1	7.82	5.10	856	- 536
298.1	8.66	5.81	1 052	- 678

**C, Diamond (20)**

0	0	0	1 282	1 282
50	0	0	1 282	1 282
100	0.29	0.063	1 282	1 276
150	1.13	.34	1 326	1 276
200	2.34	.80	1 426	1 266
250	4.18	1.45	1 589	1 227
273.1	5.02	1.82	1 698	1 207
298.1	6.19	2.28	1 806	1 126



Ca (4, 10)

T, °K	C <sub>p</sub>	S	H	F = H - TS
50	11.46	5.58	189	- 90
100	20.70	17.1	983	- 727
150	24.0	26.2	2 110	- 1 810
200	25.3	33.3	3 340	- 3 310
250	25.8	39.1	4 620	- 5 150
273.1	25.88	41.3	5 220	- 6 060
298.1	25.97	43.5	5 860	- 7 120

Cd (9, 25)

0	0	0	0	0
50	15.4	8.12	285.5	- 121
100	22.45	22.7	1 290	- 980
150	24.18	32.15	2 460	- 2 360
200	25.15	39.2	3 700	- 4 140
250	25.65	44.3	4 960	- 6 130
273.1	25.9	46.7	5 560	- 7 190
298.1	26.1	48.9	6 210	- 8 390

Cu (9, 14, 20)

50	6.02	2.47	82.2	- 41
100	16.07	10.03	648.0	- 355
150	20.85	17.52	1 603	- 1 025
200	22.9	24.0	2 700	- 2 100
250	23.95	29.25	3 860	- 3 450
273.1	24.20	31.35	4 420	- 4 130
298.1	24.45	33.60	5 020	- 4 990

Fe (9)

0	0	0	0	0
50	3.77	1.30	50.2	- 15
100	13.1	6.78	484	- 192
150	18.82	13.27	1 292	- 698
200	21.85	19.12	2 302	- 1 522
250	23.85	24.20	3 455	- 2 595
273.1	24.45	26.4	4 010	- 2 190
298.1	25.1	28.6	4 630	- 3 900

 $\frac{1}{2}\text{H}_2$  (5, 16, 31)

0	0	0	0	0
50	10.45	42.25	890	- 1 225
100	11.3	49.7	1 430	- 3 540
150	12.58	54.5	2 035	- 6 135
200	13.4	58.4	2 685	- 8 995
250	14.03	61.4	3 360	- 11 990
273.1	14.3	62.5	3 690	- 13 370
298.1	14.53	64.0	4 050	- 15 050

Hg (1, 22, 24, 28, 29)

0	0	0	0	0
50	20.9	21.7	602	- 483
100	24.65	37.6	1 768	- 1 992
150	26.2	47.8	3 040	- 4 140
200	27.2	55.4	4 380	- 6 680
273.1	28.0	74.2	7 800	- 12 500
298.1	27.6	76.5	8 500	- 14 300

 $\frac{1}{2}\text{I}_2$  (17)

T, °K	C <sub>p</sub>	S	H	F = H - TS
0	0	0	0	0
50	18.41	16.30	495	- 320
100	23.2	31.05	1 578	- 1 527
150	24.4	40.7	2 770	- 3 330
200	25.65	47.8	4 030	- 5 520
250	26.9	53.7	5 340	- 8 060
273.1	27.35	55.9	5 960	- 9 330
298.1	27.8	58.4	6 650	- 10 750

K (4, 30)

50	21.6	19.55	607	- 369
100	25.3	36.0	1 795	- 1 805
150	26.65	49.5	3 090	- 4 330
200	27.90	57.4	4 450	- 7 010
250	29.2	63.7	5 880	- 10 020
273.1	29.6	66.3	6 560	- 11 540
298.1	30.15	69.0	7 320	- 13 280

Mg (4, 21)

50	6.27	2.47	90.5	- 33
100	16.5	10.4	680	- 360
150	21.2	17.95	1 650	- 1 040
200	23.6	24.3	2 780	- 2 090
250	24.95	29.6	3 970	- 3 430
273.1	25.2	31.8	4 540	- 4 140
298.1	25.45	34.0	5 170	- 4 980

 $\frac{1}{2}\text{N}_2$  (6, 15, 27)

0	0	0	0	0
50	21.15	23.15	708	- 452
100	15.0	80.01	4 940	- 3 061
150	14.8	86.0	5 710	- 7 190
200	14.7	90.4	6 450	- 11 610
250	14.65	93.5	7 180	- 16 170
273.1	14.62	94.9	7 520	- 18 380
298.1	14.6	96.1	7 890	- 20 730

Na (9, 11, 30)

0	0	0	0	0
50	13.4	6.49	241	- 83
100	23.0	19.2	1 177	- 743
150	25.77	33.3	2 370	- 2 630
200	27.05	41.0	3 650	- 4 550
250	27.85	47.2	4 990	- 6 810
273.1	28.15	49.7	5 620	- 7 930
298.1	28.4	52.2	6 330	- 9 190

 $\frac{1}{2}\text{O}_2$  (6, 27)

0	0	0	0	0
50	22.6	26.2	965	- 345
100	15.1	84.9	5 720	- 2 770
150	14.5	90.6	6 470	- 7 130
200	14.33	94.9	7 180	- 11 810
250	14.43	98.0	7 890	- 16 610
273.1	14.53	99.4	8 230	- 18 870
298.1	14.63	100.5	8 600	- 21 400



Pb (8, 9, 13, 19, 30)

T, °K	C <sub>p</sub>	S	H	F = H - TS
0	0	0	0	0
50	21.62	21.1	577	- 478
100	23.7	37.2	1 753	- 1 967
150	25.4	47.3	2 985	- 4 115
200	25.9	54.6	4 250	- 6 650
250	26.25	60.5	5 540	- 9 580
273.1	26.35	62.8	6 140	-10 990
298.1	26.5	65.0	6 800	-12 600

S, Orthorhombic (19)

T, °K	C <sub>p</sub>	S	H	F = H - TS
0	0	0	0	0
50	7.82	6.2	182	- 128
100	12.85	13.2	605	- 715
150	16.5	19.1	1 370	- 1 490
200	19.12	24.3	2 290	- 2 570
250	21.4	28.8	3 310	- 3 890
273.1	22.17	30.2	3 810	- 4 430
298.1	23.0	32.2	4 380	- 5 220

Si (21)

T, °K	C <sub>p</sub>	S	H	F = H - TS
0	0	0	0	0
50	1.93	0.71	28.15	- 7.4
100	7.83	3.81	265.5	- 115.5
150	12.55	7.91	801	- 386
200	15.57	11.85	1 558	- 812
250	18.0	15.6	2 390	- 1 510
273.1	18.9	17.3	2 805	- 1 915
298.1	19.99	19.0	3 300	- 2 360

Sn, White (2, 17, 25)

T, °K	C <sub>p</sub>	S	H	F = H - TS
0	0	0	0	0
50	15.35	11.12	354	- 202
100	22.45	24.4	1 324	- 1 116
150	25.0	34.0	2 520	- 2 580
200	26.1	41.5	3 810	- 4 490
250	26.6	47.4	5 140	- 6 710
273.1	26.8	49.6	5 760	- 7 770
298.1	26.9	52.3	6 440	- 9 160

Sn, Gray (2, 17, 25)

T, °K	C <sub>p</sub>	S	H	F = H - TS
0	0	0	- 1 550	- 1 550
50	11.13	8.12	- 1 525	- 1 930
100	19.6	18.7	- 510	- 2 380
150	23.0	27.3	560	- 3 540
200	24.6	34.8	1 750	- 5 200
250	25.4	40.5	2 990	- 7 130
273.1	25.55	42.7	3 570	- 8 080
298.1	25.6	44.7	4 180	- 9 120

Ti (21)

T, °K	C <sub>p</sub>	S	H	F = H - TS
50	20.7	18.4	524	- 396
100	24.05	34.2	1 660	- 1 760
150	25.2	44.2	2 890	- 3 740
200	25.85	51.5	4 170	- 6 130
250	26.3	57.5	5 470	- 8 920
273.1	26.5	59.7	6 080	-10 200
298.1	26.65	62.2	6 750	-11 770

W (17)

T, °K	C <sub>p</sub>	S	H	F = H - TS
50	6.02	2.43	83.6	- 38
100	16.32	10.09	672	- 337
150	21.15	17.69	1 625	- 1 025
200	23.55	24.1	2 730	- 2 090
250	24.9	29.6	3 920	- 3 480
273.1	25.2	31.7	4 490	- 4 160
298.1	25.55	33.90	5 120	- 4 980

Zn (9, 19, 23)

T, °K	C <sub>p</sub>	S	H	F = H - TS
0	0	0	0	0
50	10.27	4.82	141	- 100
100	19.75	15.38	924	- 614
150	23.0	23.55	2 010	- 1 520
200	24.3	30.3	3 195	- 2 865
250	24.9	35.85	4 420	- 4 540
273.1	25.15	38.45	5 000	- 5 500
298.1	25.25	40.6	5 630	- 6 470

B-TABLE.—CHEMICAL COMPOUNDS, STANDARD ARRANGEMENT

H<sub>2</sub>O (24)

T, °K	C <sub>p</sub>	S	H	F = H - TS
0	0	0	-282 600	-282 600
50	8.58	4.78	-282 417	-282 656
100	16.1	13.31	-281 777	-283 108
150	21.75	20.8	-280 825	-283 945
200	23.85	27.75	-279 595	-285 145
250	34.7	34.65	-278 060	-286 720
273.1	38.2	37.85	-277 220	-287 540
298.1	75.3	66.7	-269 300	-289 200

HCl (34); HBr (35)

NH<sub>4</sub>Cl (28)

T, °K	C <sub>p</sub>	S	H	F = H - TS
0	0	0	-285 960	-285 960
50	14.69	6.49	-285 706	-286 031
100	37.7	24.2	-284 360	-286 780
150	50.2	41.5	-282 100	-288 320
200	69.4	58.8	-279 070	-290 830
250	78.9	83.1	-274 130	-294 930
273.1	82.4	90.2	-272 320	-296 920
298.1	86.6	97.6	-270 230	-299 430

CO (6, 27)

T, °K	C <sub>p</sub>	S	H	F = H - TS
0	0	0	-125 948	-125 948
50	45.2	30.75	-124 918	-126 458
100	32.0	159.3	-115 218	-131 148
150	29.9	171.9	-113 718	-139 518
200	29.65	180.0	-112 228	-148 228
250	29.45	186.5	-110 748	-157 348
273.1	29.4	189.2	-110 068	-161 668
298.1	29.35	192.0	-109 348	-166 548

C<sub>2</sub>H<sub>6</sub> (18, 19, 32)

T, °K	C <sub>p</sub>	S	H	F = H - TS
0	0	0	49 050	49 050
50	34.65	22.8	49 656	48 516
100	55.8	53.5	52 000	46 650
150	73.9	79.5	55 390	43 490



**C<sub>6</sub>H<sub>6</sub>—(Continued)**

<i>T</i> , °K	<i>C<sub>p</sub></i>	<i>S</i>	<i>H</i>	<i>F</i> = <i>H</i> - <i>TS</i>
200	103.0	102.5	59 670	39 170
250	110.5	124.4	64 850	33 750
273.1	118.8	135.0	67 500	30 700
298.1	133.5	181.0	80 850	26 850

**SiC (10, 21)****PbO (21)**

0	0	0	-213 660	-213 660
50	16.6	12.3	-213 250	-213 865
100	28.45	27.6	-212 110	-214 870
150	36.55	43.5	-210 485	-217 005
200	41.8	54.6	-208 540	-219 440
250	44.9	64.2	-206 390	-222 390
273.1	46.1	68.5	-205 320	-224 020
298.1	47.2	72.5	-204 140	-225 740

**PbCl<sub>2</sub> (19)**

0	0	0	-329 460	-329 460
50	40.9	29.6	-328 556	-330 036
100	59.2	64.9	-325 945	-332 435
150	68.0	90.7	-322 700	-336 300
200	72.6	111.0	-319 180	-341 380
250	75.4	127.2	-315 540	-347 340
273.1	76.2	134.1	-313 780	-350 380
298.1	76.9	140.9	-311 880	-353 880

**PbS (4)**

0	0	0	-93 860	-93 860
50	26.8	19.5	-93 254	-94 229
100	39.6	43.0	-91 542	-95 842
150	44.4	60.0	-89 420	-98 420
200	47.5	73.3	-87 120	-101 770
250	49.7	84.0	-84 710	-105 710
273.1	50.4	88.4	-83 540	-107 640
298.1	51.4	92.8	-82 260	-109 960

**TiCl (24)**

0	0	0	-191 020	-191 020
50	33.95	27.4	-190 163	-191 533
100	44.7	54.8	-188 136	-193 616
150	48.2	73.6	-185 800	-196 800
200	50.3	87.5	-183 350	-200 850
250	51.8	99.9	-180 520	-205 520
273.1	52.4	103.3	-179 320	-207 520
298.1	53.0	108.0	-178 000	-210 200

**ZnS (10)**

0	0	0	-190 750	-190 750
50	14.59	7.99	-190 465	-190 865
100	25.8	21.7	-189 376	-191 546
150	33.5	33.4	-187 715	-192 715
200	38.95	43.8	-185 790	-194 540
250	43.1	52.8	-183 710	-196 910
273.1	45.0	56.7	-182 680	-198 160
298.1	46.6	60.6	-181 500	-199 500

**HgO (10)**

<i>T</i> , °K	<i>C<sub>p</sub></i>	<i>S</i>	<i>H</i>	<i>F</i> = <i>H</i> - <i>TS</i>
0	0	0	-83 020	-83 020
50	18.18	12.13	-82 631	-83 236
100	29.3	28.45	-81 409	-84 254
150	36.0	41.7	-79 725	-85 975
200	40.3	52.5	-77 810	-88 310
250	43.4	61.8	-75 840	-91 290
273.1	44.5	65.6	-74 830	-92 730
298.1	45.3	69.6	-73 700	-94 500

**HgCl (24)**

0	0	0	-115 500	-115 500
50	28.6	21.3	-114 814	-115 879
100	39.55	45.0	-113 075	-117 575
150	45.0	62.3	-110 960	-120 300
200	48.0	75.7	-108 660	-123 760
250	50.0	86.5	-106 250	-127 850
273.1	50.5	90.9	-105 090	-129 890
298.1	51.0	95.4	-103 820	-132 220

**CuI (28)**

0	0	0	-68 520	-68 520
50	28.05	19.2	-67 892	-68 852
100	41.9	43.7	-66 080	-70 450
150	47.1	61.6	-63 830	-73 080
200	50.0	75.5	-61 420	-76 520
250	52.1	86.8	-58 870	-80 570
273.1	53.0	91.4	-57 690	-82 590
298.1	53.8	96.0	-56 330	-84 930

**AgCl (19, 21)**

0	0	0	-114 090	-114 090
50	28.15	20.8	-113 408	-114 448
100	41.0	45.0	-111 650	-116 150
150	46.0	62.8	-109 490	-118 920
200	49.0	76.4	-107 110	-122 390
250	51.4	87.5	-104 620	-126 495
273.1	53.1	92.1	-103 410	-128 510
298.1	53.8	96.7	-102 090	-130 890

**AgI (21)**

0	0	0	-63 220	-63 220
50	31.9	28.65	-62 388	-63 820
100	45.7	55.7	-60 390	-65 960
150	50.8	75.4	-58 010	-69 310
200	52.7	90.0	-55 480	-73 480
250	53.8	102.0	-52 640	-78 140
273.1	54.1	106.4	-51 440	-80 540
298.1	54.4	111.3	-50 120	-83 320

**FeS<sub>2</sub> (8)**

0	0	0	-144 750	-144 750
50	2.64	0.83	-144 720	-144 761
100	18.84	7.11	-144 226	-144 937
150	36.66	18.4	-142 870	-145 630
200	49.59	30.75	-140 680	-146 830
250	57.3	42.7	-137 990	-148 640
273.1	60.0	47.8	-136 630	-149 730
298.1	62.1	53.0	-135 100	-150 900



**MgO (10, 26)**

T, °K	C <sub>p</sub>	S	H	F = H - TS
0	0	0	-600 680	-600 680
50	0.42	0.29	-600 660	-600 674
100	6.91	2.18	-600 497	-600 715
150	19.3	7.45	-599 822	-600 940
200	27.65	14.10	-598 590	-601 410
250	34.35	21.0	-597 010	-602 260
273.1	36.9	24.2	-596 180	-602 780
298.1	39.6	27.5	-595 230	-603 430

**CaO (21)**

0	0	0	-627 740	-627 740
50	2.85	0.88	-627 705	-627 749
100	16.4	6.56	-627 251	-627 907
150	28.8	15.4	-626 070	-628 370
200	37.3	24.75	-624 460	-629 400
250	41.3	33.4	-622 570	-630 920
273.1	42.9	37.18	-621 620	-631 770
298.1	44.2	40.8	-620 540	-632 740

**CaF<sub>2</sub> (8)**

0	0	0		
50	4.27	1.59		
100	19.3	8.99		
150	31.4	18.99		
200	38.1	29.95		
250	42.5	37.85		
273.1	44.0	41.7		
298.1	45.1	45.6		

**CaCO<sub>3</sub>, Calcite (21)**

0	0	0	-1 191 410	-1 191 410
50	15.9	7.07	-1 191 118	-1 191 468
100	41.1	25.7	-1 189 690	-1 192 260
150	57.4	45.8	-1 187 260	-1 194 140
200	68.1	63.6	-1 184 250	-1 196 950
250	75.6	79.2	-1 180 710	-1 200 510
273.1	78.2	85.9	-1 178 990	-1 202 390
298.1	80.4	92.6	-1 177 000	-1 204 600

**LiH (11)**

0	0	0		
50	0.84	0.25		
100	6.28	2.09		
150	14.68	6.19		
200	23.3	11.68		
250	30.3	17.6		
273.1	32.35	20.45		
298.1	34.5	23.55		

**NaCl (20)**

T, °K	C <sub>p</sub>	S	H	F = H - TS
0	0	0	-396 520	-396 520
50	15.08	6.15	-396 263	-396 570
100	34.95	23.75	-394 866	-397 241
150	42.7	39.7	-392 910	-398 860
200	46.7	52.6	-390 720	-401 220
250	49.0	63.2	-388 390	-404 190
273.1	49.6	67.6	-387 270	-405 770
298.1	50.0	72.0	-386 000	-407 400

**KBr (20)**

0	0	0	-386 190	-386 190
50	29.5	16.14	-385 587	-386 397
100	42.6	42.1	-383 675	-387 885
150	46.8	60.2	-381 440	-390 490
200	48.9	74.1	-379 090	-393 890
250	50.6	85.0	-376 660	-397 860
273.1	51.3	89.5	-375 480	-399 880
298.1	51.8	94.2	-374 220	-402 220

**KCl (20)**

0	0	0	-421 300	-421 300
50	21.1	9.71	-420 914	-421 399
100	39.6	31.0	-419 319	-422 419
150	45.1	50.2	-417 190	-424 720
200	47.7	63.5	-414 860	-427 560
250	49.4	74.2	-412 400	-430 900
273.1	50.1	78.6	-411 280	-432 700
298.1	50.6	83.1	-410 000	-434 780

**Al<sub>2</sub>(SO<sub>4</sub>)<sub>3</sub>·Cs<sub>2</sub>SO<sub>4</sub>·12H<sub>2</sub>O (36)****LITERATURE**

(For a key to the periodicals see end of volume)

- (1) Bridgman, 65, 47: 345; 11. (2) Brönsted, 7, 88: 479; 14. (3-5) Dana and Onnes, 64P, 29: 1051, 1061; 26. (3) Dewar, 5, 89: 158; 13. (4) Eastman and Rodebush, 1, 40: 489; 18. (5) Eucken, 76, 1912: 141. (6) Eucken, 88, 18: 4; 16. (7) Eucken and Karwat, 7, 112: 467; 24. (8) Eucken and Schwes, 88, 18: 578; 13. (9) Griffiths and Griffiths, 5, 29: 557; 14. (10) Günther, 8, 51: 828; 16. (11) Günther, 8, 68: 476; 20. (12) Heuse, 8, 89: 86; 19. (13) Keesom and Onnes, 64P, 23: 792; 14. (14) Keesom and Onnes, 64P, 18: 484; 15. 168, No. 147a. (15) Keesom and Onnes, 64P, 18: 1247; 16. 168, No. 149a. (16) Keesom and Onnes, 64P, 20: 1000; 18. 168, No. 153a. (17) Lange, 7, 110: 343; 24. (18) Maass and Waldbauer, 1, 47: 1; 25. (19) Nernst, 8, 36: 395; 11. (20) Nernst and Lindemann, 9, 17: 817; 11. (21) Nernst and Schwes, 76, 1914: 355. (22) Onnes and Holst, 64P, 17: 760; 14. 168, No. 143c. (23) Pollitzer, 9, 17: 5; 11. (24) Pollitzer, 9, 19: 513; 13. (25) Rodebush, 1, 44: 1413; 23. (26) Russell, 63, 12: 59; 12. (27) Scheel and Heuse, 8, 40: 473; 13. (28) Simon, 8, 68: 241; 22. (29) Simon, 7, 107: 279; 23. (30) Simon, 7, 110: 572; 24. (31) Simon and Lange, 96, 15: 312; 23. (32) Williams and Daniels, 1, 46: 1569; 24. (33) Barnes and Cooke, 8, 16: 65; 03. (34) Glaue and Wiebe, 1, 50: 101; 28. (35) Glaue and Wiebe, 1, 50: 2193; 28. (36) Latimer and Greensfelder, 1, 50: 2202; 28.



HEAT CAPACITY OF SOLID AND LIQUID ELEMENTARY SUBSTANCES ABOVE 0°C\*  
LUIGI ROLLA AND GIORGIO PICCARDI

Where possible the information is presented in the form of the parameters of the equation  $C_p = A + Bt + Ct^2 + \dots$ , where  $C_p$  is the atomic heat capacity in joules per gram atom per °C and  $t$  is the centigrade temperature.

Column two contains the value of the parameter  $A$ ; column three, the value of  $10^3B$ ; column four, the temperature range covered by the data from which the equation was derived. When the letter  $M$  appears in column three, the value in column two is the mean heat capacity,  $C_m$ , over the temperature range given in column four. When a single temperature appears in column four, the value in column two is the heat capacity at that temperature. Values in bold-face type are "best" values as deduced from all of the information available. The accuracy of these values is difficult to estimate, but, in general, it may be stated that specific heat data on metals are rarely accurate to better than 1%, an uncertainty of several % being not unusual.

In cases where no "best" values are given, the available information is discordant, or lacks confirmation. In many cases information of this character is indicated by literature reference only.

L'information est présentée partout où cela est possible sous la forme des paramètres de l'équation  $C_p = A + Bt + Ct^2 + \dots$ , où  $C_p$  est la capacité calorifique atomique exprimée en joules par atome gramme et par °C et  $t$  est la température centigrade.

La deuxième colonne contient la valeur du paramètre  $A$ ; la troisième colonne, la valeur de  $10^3B$ ; la quatrième colonne, l'intervalle de température comportant les données à partir desquelles on a déduit l'équation. Lorsque la lettre  $M$  se trouve dans la troisième colonne, la valeur dans la deuxième colonne, représente la capacité calorifique moyenne  $C_m$ , pour l'intervalle de température donné dans la quatrième colonne. Lorsqu'il n'y a qu'une seule température dans la quatrième colonne, la valeur dans la deuxième colonne est la capacité calorifique à cette température. Les valeurs en caractères gras sont les "meilleures" valeurs, telles qu'on les a déduites de toute l'information disponible. La précision de ces valeurs est difficile à estimer, mais, en général il peut être établi que les données de chaleur spécifique se rapportant aux métaux sont rarement d'une précision supérieure à un pour cent, une incertitude de plusieurs pour cent n'étant pas rare.

Dans les cas où les "meilleures" valeurs ne sont pas données, l'information disponible est discordante, ou a besoin de confirmation. Dans plusieurs cas l'information présentant ce caractère n'est indiquée que par une référence bibliographique.

\* For data below 0°, v. p. 84.

Wo möglich ist die Angabe durch die Parameter der Gleichung  $C_p = A + Bt + Ct^2 + \dots$ , gegeben. Hier bedeutet  $C_p$  den Atomwärmehalt in Joule pro Grammatom und pro °C, und  $t$  ist die Centigrad Temperatur.

Kolonne zwei enthält die Werte des Parameters  $A$ , Kolonne drei, von  $10^3B$ ; Kolonne vier den Temperaturbereich aus welchem die Daten bei der Ableitung der Gleichung herangezogen worden sind. Erscheint der Buchstabe  $M$  in der Kolonne drei, dann ist der Wert in der Kolonne zwei der mittlere Wärmehalt  $C_m$  in dem Temperaturbereich, welcher in der Kolonne vier angegeben ist. Erscheint in der Kolonne vier eine einzelne Temperaturangabe, so ist der in der Kolonne zwei angegebene Wärmehalt für diese Temperatur gültig. Zahlen in hervorgehobener Schrift stellen die "besten" dar, die sich aus allen zur Verfügung stehenden Werten ableiten liessen. Die Genauigkeit solcher Werte ist schwer zu schätzen, man kann jedoch im allgemeinen feststellen, dass die spezifischen Wärmen der Metalle selten genauer als auf 1% bekannt sind und Unsicherheiten bis auf einige Prozente kommen nicht selten vor.

In Fällen wo kein "beste" Werte angegeben sind, werden die vorliegenden Ergebnisse widersprechend sein, oder es fehlen Bestätigungen. In vielen Fällen sind Ergebnisse dieser Art nur durch die Literaturstellen angegeben.

Tutte le volte che è possibile, i valori sono riportati in forma di parametri dell'equazione:  $C_p = A + Bt + Ct^2 + \dots$ , nella quale  $C_p$  è il calore atomico in joules per grammo atomo e per °C, e  $t$  è la temperatura in gradi centigradi.

La colonna 2 contiene i valori di  $A$ ; la 3 i valori di  $10^3B$ ; la 4 l'intervallo di temperatura al quale si riferiscono i dati da cui è stata dedotta l'equazione. La lettera  $M$  nella colonna 3 indica che il valore della colonna 2 è il calore specifico medio,  $C_m$ , entro l'intervallo indicato nella colonna 4. Quando nella colonna 4 è indicata una sola temperatura, il valore riportato nella 2 rappresenta il calore specifico a quella temperatura. I valori in grassetto sono quelli "ottimi" quali si deducono da tutte le fonti disponibili. È difficile apprezzare l'esattezza di questi valori; in genere però si può dire che essa per i metalli raramente supera 1%, e che non sono infrequenti scarti superiori.

Quando non sono riportati valori "ottimi," significa che i dati disponibili non sono concordanti tra loro, oppure che non sono confermati. In molti casi, i dati di questo tipo sono riportati solo sotto forma di indicazioni bibliografiche.

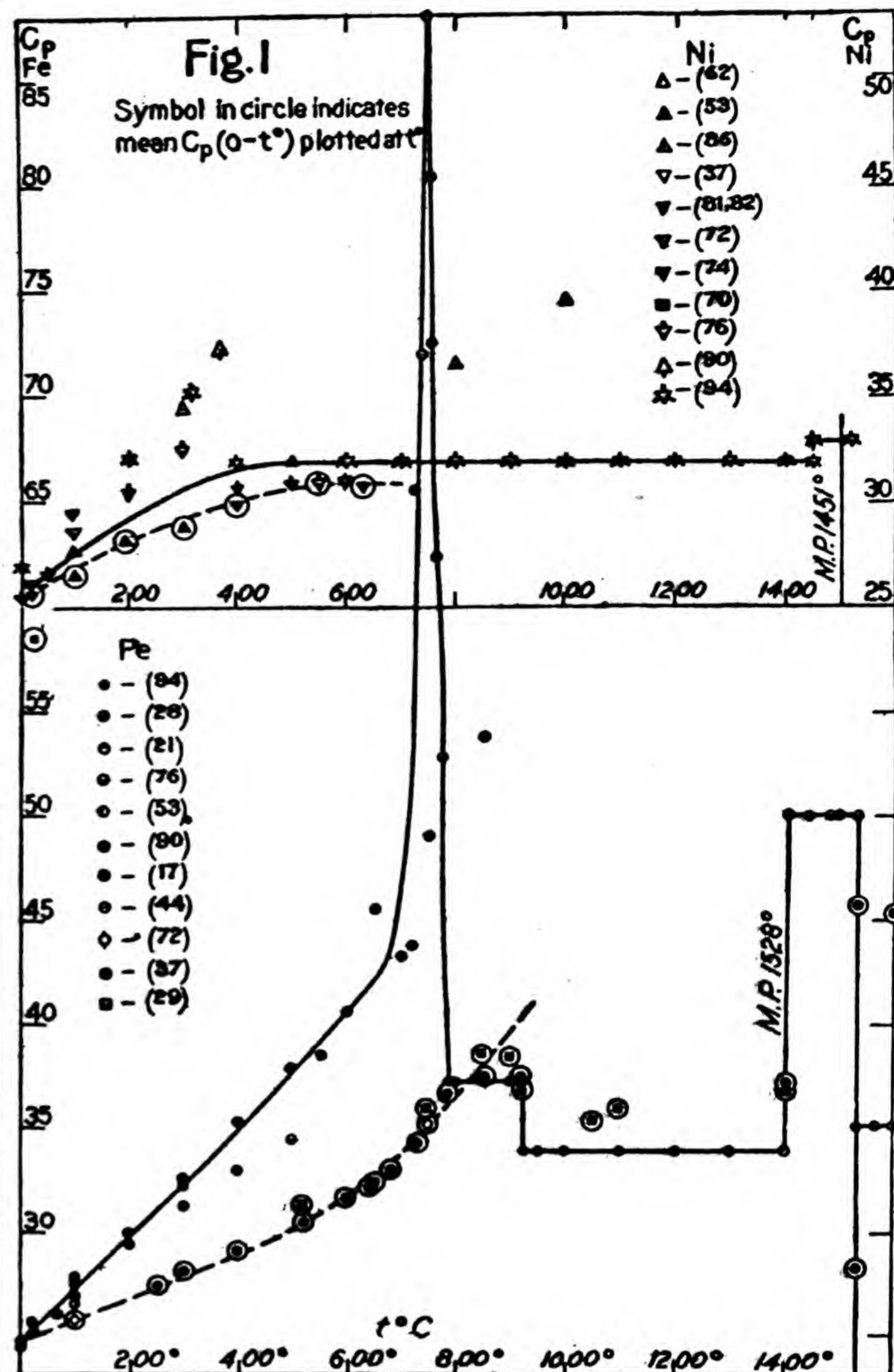
SOLIDS

	$C_p$ , $C_m$ or $A$	$10^3B$	$t$ , or $\Delta t$ , °C	Lit.
Al	<b>23.42</b> <b>26.0</b> <b>24.52</b>	<b>18.4</b>  <b>9.82</b>	0-100 150 200-300	(4, 9, 27, 28, 53, 56, 76, 94)
Ag	24.7	11	100-590	(19)
As	<b>25.11</b> 24.2	<b>6.03</b>  M	0-961 28 0-100	(19, 94) (21) (92); cf. (7)
Au	<b>25.44</b>	<b>4.92</b>	0-400	(37, 72, 94)

	$C_p$ , $C_m$ or $A$	$10^3B$	$t$ , or $\Delta t$ , °C	Lit.
Au.—(Cont'd)	25.4	5.6	20-850	(73)
	Higher temps.		to 1060	(83, 94)
B	1.005	M	-253 to -196	(16)
"Amorph."	3.22	M	-191 to -78	(40)
"Amorph."	7.60	M	-74 to 0	(40)
	9.90	33.1	400-900	(49.2)
	Higher temps.		to 230	(51, 87)
Ba	20	M	-253 to -196	(15, 16)
	39.1	M	-185 to 20	(70)



	$C_p$ $C_m$ or A	10°B	$t$ , or $\Delta t$ , °C	Lit.
Be	0.52	M	-253 to -196	(16)
	Higher temps.		to 300	(34, 58, 59)
Bi	25.41	11.6	25-200	(36, 37, 76, 94)
	Higher temps.		to 250	(83)
C	v. p. 94			
Ca $\alpha$	25.5	M	0-157	(6, 10)
	25.5	17.5	100-400	(19)
Ca $\beta$	27.7	6.38	400-600	(19)
Cd	25.76	11.0	0-321	(14, 22, 23, 27, 37, 53, 69, 94)
Ce	26.3	M	0-100	(32)
	30.0	M	20-100	(33)
Co	15.65	55.4	-84 to -34	(76, 81)
	24.40	18.2	0-300	(12, 16, 24, 76)
	22.5	20	0-950	(94)
	27.3	7.2	1100-1470	(94); cf. (83)
Cr	22.4		0	(46, 70, 72, 76, 94)
	23.6		50	
	24.4		100	
	25.6		200	
	26.6		300	
	28.1		400	
	Higher temps.		to 1600	(83, 94)
Cs	29.0	15	0-28	(66)
Cu	24.33	6.63	0-500	(30, 53, 72, 76)
	Higher temps.		to 1000	(23, 43, 67, 83, 94, 95)
Fe	24.51	24.6	0-300	(17, 29, 90, 94; cf. 83)
	v. Fig. 1		to 1600	cf. (95)
Ge	24	M	0-440	(59)
Hg	v. p. 113			
I	27.84		1.8	(55)
In	27.4	M	0-100	(10)
Ir	26.1	M	0-100	(3, 88)
	Other values		-186 to 1400	(3, 85)
K	29.78		13.6	(18)
	28.3	4.7	0-63	(66)
	30.7	M	0-22	(5)
	31.4	M	22-56	(5)
La	26	M	0-100	(32)
Li	23		0	(39, 42)
	31.7	M	0-100	(6)
Mg	24.46	12.7	0-300	(19, 72)
	25.1	10.9	100-615	(19)
	Higher temps.		to 600	(47, 76, 78)
Mn			0-1250	(42, 78, 94)
Mo	5.7		-223	(16)
	20.3	M	-188 to +20	(68)
	Other values		0-1500	(12, 78, 94)
Na	28.2		0	(39)
	27.1		0	(66)
	27.2*			(11, 26)
	27.6†			(28)
	28.6	M	0-20	(5)
	28.4		20.4	(18)
	27.1	45	0-97	(66)
	27.2	27	0-70	(11, 26, 27, 28)
	22.5	93	70-97	(11, 26, 27, 28)
Ni	25.34	25.0	0-200	(72, 76)
	v. Fig. 1		to 1400	(62, 76, 81, 82, 90, 94); cf. (79, 83, 95)



	$C_p$ $C_m$ or A	10°B	$t$ , or $\Delta t$ , °C	Lit.
Os	25		23	(65)
P, red	28.10	58.2	0-200	(92)
	24.64		9	(21)
White	23.01		9	(21)
Black	22.1		30-100	(45)
	26.6		50-100	(61)
Pb	26.19	10.4	0-327	(4, 27, 28, 37, 52, 81, 82)
Pd	8.5	M	-263 to -196	(16)
	23.1	M	-188 to +20	(68)
	21.9	M	-186 to -79	(4)
	25.3	M	-79 to +18	(4)
	25.98	9.04	0-1260	(85)
	26.17		18	(37)
	27.56		100	(37)
Pt	25.71	5.45	0-800	(22, 37, 74, 80, 81, 82, 84, 91, 94)
	25.89	5.23	300-1300	(91)

\* Cooled slowly. † Quenched.



	$C_p$ , $C_m$ or A	10 <sup>3</sup> B	$t$ , or $\Delta t$ , °C	Lit.
Rb	28.3	M	20-35	(14)
	28.68	10.8	0-39	(66)
	32.5		50	(66)
Rh	25.0		10-100	(65)
Ru	26.0	M	0-100	(10)
S, rhomb.	23.0	M	0-35	(55, 92)
	23.6	M	0-95	(92)
Monocl.	24.0	M	0-38	(55, 92)
	24.3	M	0-52	(92)
Sb	25.13	74.5	0-300	(4, 68, 72, 76)
	Higher temps.		to 630	(38, 76, 94)
Se	25.6	M	22-62	(7)
Si	20.41	15.16*	0-700	(49)
Sn	26.53	17.3	0-100	(4, 22, 45.1, 45.2, 72, 76)
	Higher temps.		to 500	(83, 95)
Gray	24.5	M	8 to 13	(11.5)
White	26.7	M	13 to 18	(11.5)
Ta	21	M	-183 to -78	(77)
	24.3	M	-78 to +14	(77)
	25.1	M	14-100	(77)
	Higher temps.		to 1400	(63)
Te	25.58	3.7	-182 to +300	(82)
Th	26.8	M	0-100	(57)
Ti	16.5	M	-185 to +20	(60)
	28.6	15.6	0-300	(35)
Tl	26.6		+28	(21)
	25.3	M	-180 to +20	(68)
	24.6	M	-190 to -81.2	(71)
	26.0	M	-74 to $\pm 0$	(71)
	28.66	M	17-100	(64)
	27.9	M	20-100	(75)
U		M	0-100	(8, 64)
V	24.6	M	0-100	(46)
W	26.1	M	17-97	(13, 25)
	21.06	6.5	700-2500	(93) <i>q.v.</i> for additional Lit.; <i>cf.</i> (49.2)
Zn	25.10	11	0-300	(19, 27, 53, 72, 76)
	Higher temps.		to 400	(83)
Zr	25.5	M	0-100	(50, 89)

\*  $C = -9.15 \times 10^{-4}$ .

C, Graphite (48, 73, 87)

$t$ , °C	$C_p$	$t$ , °C	$C_p$	$t$ , °C	$C_p$
0	7.63	90	10.88	180	13.42
10	8.05	100	11.15	190	13.68
20	8.39	110	11.43	200	13.93
30	8.78	120	11.73	210	14.16
40	9.12	130	12.04	220	14.42
50	9.47	140	12.31	230	14.66
60	9.82	150	12.59	240	14.88
70	10.17	160	12.88	250	15.11
80	10.49	170	13.18		

The determinations by Magnus (49) between 10 and 830°C are represented by the equation,

$$C_p = 7.635 + 39.06 \times 10^{-4}t - 43.02 \times 10^{-6}t^2 + 29.57 \times 10^{-8}t^3 - 11.01 \times 10^{-10}t^4$$

According to Worthing's determinations (93),  $C_p = 19.5 + 0.0035t$  in the range 900-2100°.

Acheson graphite (1)

$t$ , °C	$C_p$	$t$ , °C	$C_p$
26-76	8.29	35-900	16.3
26-280	9.83	40-925	16.3
25-490	11.3	48-1193	17.6
30-540	11.7	56-1450	19.6
30-750	14.5		

For natural graphites, coke, charcoal, etc., *v.* (7, 15, 16, 31, 41, 73, 80, 84, 85, 87, 93).

C, Diamond (48, 49, 56)

New determinations between 500 and 900° are given in (49.5)

$t$ , °C	$C_p$	$t$ , °C	$C_p$	$t$ , °C	$C_p$
0	5.24	350	17.06	720	21.14
10	5.66	400	17.88	740	21.24
20	6.08	450	18.58	760	21.33
30	6.50	500	19.24	780	21.41
40	6.92	520	19.47	800	21.48
50	7.34	550	19.80	820	21.54
100	9.44	600	20.26	840	21.58
200	13.50	650	20.70	860	21.59
250	15.01	700	21.04	880	21.60
300	16.14				

## LIQUIDS

Almost no reliable data exist on the specific heats of liquid elements. Some of the data found in the literature are presented below.

In the following table the quantity given is  $\Delta = C_p(\text{solid}) - C_p(\text{liq.})$  at the melting point; joules per gram atom per deg. C.

Element	$\Delta$	Lit.	Element	$\Delta$	Lit.	Element	$\Delta$	Lit.
Ag	2.9	(83)	Co	1.5	(94)	Pb	1.6	(36)
Al	2.5	(83, 94)		-8.6	(83)		0.47	(83)
			Cr	11	(83)	Sb	0.7	(94)
Au	1.8	(94)	Cu	1.8	(94)		-3.7	(83)
	8.2	(83)		4.2	(83)	Sn	3.1	(94)
Bi	0.2	(94)	Fe	15	(94)		2.3	(36)
	1.5	(36, 83)		-8.1	(83)		11.1	(83)
			Ni	-1.0	(94)	Zn	1.2	(94)
Cd	6.9	(94)		-9.2	(83)		-3.0	(36)
	0.4	(83)	Pb	1.2	(94)		-3.8	(83)

Br,  $C_p = 35.8$ , 1 to 45° (2).

Cs,  $C_p = 33.6 - 0.019t$ , M. P. to 100° (66).

Hg, *v.* p. 113.

K,  $C_p = 23.2 + 0.109t$ , M. P. to 100° (66).

Na,  $C_p = 31.1$  at 100° (26, 28, 39); 31.8 at 98° (66); 33.4 at 98° (36). Decreases with rising temperature (26, 28).

Rb,  $C_p = 32.9 - 0.0093t$ , M. P. to 100° (66).

S,  $C_p = 28.2 + 0.0215t$ , 100 to 390° (45). For "viscous" S, *v.* (52).

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## THE HEAT CAPACITY OF CHEMICAL COMPOUNDS IN THE CRYSTALLINE STATE

J. H. AWBERY

B-TABLE, STANDARD ARRANGEMENT (Vol. III, p. viii)

U = Transition temperature

Substance	t or $\Delta t$ , °C	$c_p$ , joule/g	$\pm$ %	Lit.
H <sub>2</sub> O.....	-250	0.151	2.5	(5, 125, 193,
	-200	0.653	2	194, 235,
	-150	1.030	1	236)
	-100	1.39	1	
	-80	1.54	1	
	-60	1.68	1	
	-40	1.82	0.5	(5, 10, 70,
	-20	1.94	0.5	125, 193,
	0	2.06	0.5	194, 195,
				229, 235,
				236, 244)
H <sub>2</sub> O <sub>2</sub> .....	-25	1.97	4	(161)
HCl, HBr, and HI, v. p. 86.				
SO <sub>2</sub> .....	-185 to -103	0.96	5	(67)
H <sub>2</sub> SO <sub>4</sub> .....	-30	1.00	2	(230, 232)
	-20	1.10		
	-10	1.09		
	0	1.13		
H <sub>2</sub> S <sub>2</sub> O <sub>7</sub> .....	35	0.64		(6)
NO.....				
N <sub>2</sub> O.....	-80 to 5	1.00	2	(261)
NH <sub>3</sub> .....	-103 to -188	2.1	5	(67)
NH <sub>4</sub> NO <sub>3</sub> .....	-150	0.790	1	(23, 86, 322)
	-100	1.280	0.5	
	-50	1.526		
	0	1.661	0.25	
	+50	1.735		
	100	1.790		
NH <sub>4</sub> Cl.....	-250	0.041	1	(282); cf.
	-225	0.267		(42, 67, 86,
	-200	0.506		137, 199)
	-150	0.824		
	-100	1.100	0.5	
	-80	1.217		
	-30U			
	-20	1.460		
	0	1.495		
	+50	1.63	1	
NH <sub>4</sub> Cl <sub>2</sub> .....	185	1.96	3	(264)
NH <sub>4</sub> Cl <sub>3</sub> .....	185	1.42	3	(264)
NH <sub>4</sub> Br.....	-140	0.547	0.5	(86)
	-100	0.726	1	
	-60	0.809		
	-20	0.854		
	+20	0.879		
	60	0.888		
NH <sub>4</sub> I.....	-150	0.406	1	(86)
	-100	0.431		

Substance	t or $\Delta t$ , °C	$c_p$ , joule/g	$\pm$ %	Lit.
NH <sub>4</sub> I.—(Cont'd)....	0	0.464	0.5	
	+50	0.494		
(NH <sub>4</sub> ) <sub>2</sub> SO <sub>4</sub> .....	-200	0.335	5	(86, 125, 132,
	-150	0.816		137)
	-100	1.184	2	
	0	1.409	0.5	
	+50	1.443	1	
PCl <sub>5</sub> .....	33	0.85	2	(240, 241)
As <sub>2</sub> O <sub>3</sub> .....	-150	0.230	2	(240, 262)
	-100	0.318	1	
	0	0.489		
	40	0.509		
AsCl <sub>3</sub> .....	56	0.74	2	(240)
Sb <sub>2</sub> O <sub>3</sub> .....	60	0.391	2	(199, 240)
Sb <sub>2</sub> S <sub>3</sub> .....	-150	0.226	1	(240, 262)
	-100	0.295		
	-50	0.330		
	0	0.347		
	+50	0.360		
	100	0.370		
Bi <sub>2</sub> O <sub>3</sub> .....	50	0.238	2	(112, 240)
	100	0.248		
	200	0.258		
	300	0.264		
	400	0.268		
Bi <sub>2</sub> S <sub>3</sub> .....	50	0.251	2	(240)
CO.....	-230	0.239	1	(83)
	-240	0.705	0.25	
	-220	1.746		
	-213U			
	-212	1.792	0.25	
	-206	1.911		
CO <sub>2</sub> .....	-260	0.046	8	(67, 83, 160)
	-250	0.153	6	
	-225	0.52	4	
	-200 to -75	1.660 + 0.00484	3	
C <sub>2</sub> N <sub>2</sub> .....	-188 to 78	0.70	6	(86)
For other C-Compounds, v. p. 101				
v. p. 105				
SiO <sub>2</sub> .....	-200 to -80	0.990 + 0.002784	1	(143)
SiCl <sub>4</sub> .....	-240	<0.001		
SiC.....	-220	0.0092	8	
	-200	0.044	2	
	-100	0.341	1	(60, 106,
	0	0.60		171, 196,
	+100	0.81	1	262, 313)
	200	0.96		
	400	1.09	2	
	600	1.17		



Substance	$t$ or $\Delta t$ , °C	$c_p$ , joule/g	$\pm$ %	Lit.	Substance	$t$ or $\Delta t$ , °C	$c_p$ , joule/g	$\pm$ %	Lit.
SiC.—(Cont'd)	800	1.23			ThO <sub>2</sub> —(Cont'd)	0	0.239		
	900	1.24				+ 50	0.246		
TiO <sub>2</sub>	0 to 500	0.703 + 0.000456t	3	(203, 240)	ThCl	30	1.70	3	(87)
TiCl <sub>4</sub>	-200	0.394	0.5	(143, 240)	Th(SO <sub>4</sub> ) <sub>2</sub>	50	0.41	2	(203)
	-175	0.353			In <sub>2</sub> O <sub>3</sub>	50	0.338	2	(203)
	-150	0.624			TiCl	-250	0.056	2	(98, 236, 263)
	-100	0.717				-230	0.1280	0.5	
	-25	0.739				-200	0.1677		
GeO <sub>2</sub>	50	0.54	2	(203)		-150	0.1931		
ZrO <sub>2</sub> .SiO <sub>2</sub> , Zircon	36	0.55	2	(137, 204)		-100	0.2047		
ZrO <sub>2</sub>	0 to 1500	0.433 + 0.000208t	2	(44, 202)		0	0.2175		
SnO <sub>2</sub>	45	0.376	2	(137, 240)		+100	0.227		
SnCl <sub>2</sub>	60	0.427	2	(240)		200	0.233	1	
SnCl <sub>4</sub>	-200	0.314	0.5	(143, 240, 241)		400	0.242	2	
	-150	0.428				390	0.220	2	(87)
	-100	0.482			TlBr				
	-50	0.529			TlC <sub>2</sub> H <sub>2</sub> N <sub>2</sub> O <sub>7</sub>				
SnS	56	0.351	2	(240)	picrate (red)	10	0.573	1	(48)
SnS <sub>2</sub>	54	0.50	2	(240)	(yellow)	10	0.560	1	(48)
PbO	-250	0.0313	1	(137, 170, 198, 240, 262, 299)	ZnO	-200	0.158	3	(64, 170, 173, 240)
	-200	0.1012				-100	0.35		
	-150	0.139				0	0.477	1	
	-100	0.166				+100	0.541		
	-50	0.188				200	0.577		
	0	0.202				400	0.62	2	
	+ 50	0.213				600	0.64		
	100	0.218				800	0.66		
	200	0.222				1000	0.68		
PbO <sub>2</sub>	-150	0.151	2	(215, 262)		1200	0.69		
	-50	0.232			ZnCl <sub>2</sub>	60	0.57	2	(240)
	0	0.259			ZnS, Sphalerite	-260	0.0088	5	(100)
	+ 50	0.272				-240	0.0790	0.5	
PbF <sub>2</sub>	9	0.301	2	(271)		-220	0.155		
PbCl <sub>2</sub>	-260	0.0238	3	(48, 78, 82, 98, 147, 169, 194, 271)		-200	0.202	2	
	-240	0.0970	2			-260	0.029	3	(106, 117, 132, 137, 147, 199, 240)
	-220	0.1568				-240	0.253	0.5	
	-200	0.1920	1			-220	0.386		
	-150	0.2271	0.5			-200	0.430	1	
	-100	0.2497				-175	0.453		
	0	0.2718	0.2			-150	0.464		
	+100	0.2848	0.5			-100	0.477	2	
	200	0.2948				0	0.486		
	300	0.310	1			+100	0.493		
	400	0.335	3			200	0.502		
PbBr <sub>2</sub>	-150	0.107	10	(13, 78, 98, 240, 271)		400	0.510		
	-50	0.187	3		ZnSO <sub>4</sub>	50	0.73	2	(216)
	0	0.210	1		ZnSO <sub>4</sub> .H <sub>2</sub> O	9	0.81	2	(286)
	+ 50	0.222			ZnSO <sub>4</sub> .6H <sub>2</sub> O	9	1.25	2	(286)
	100	0.227			ZnSO <sub>4</sub> .7H <sub>2</sub> O	-250	0.063	3	(58, 88, 135, 137, 216, 235, 236, 256, 270, 271)
	200	0.230				-200	0.409	1	
	400	0.235				-150	0.738	0.5	
PbI <sub>2</sub>	-250	0.0706	1	(198)		-100	0.960		
	-225	0.1205				0	1.346	0.25	
	-200	0.1380	0.5	(13, 78, 138, 169, 198, 240, 271)		+ 50	1.437	0.5	
	-150	0.1531			Zn(NO <sub>3</sub> ) <sub>2</sub> .6H <sub>2</sub> O	30	1.33	1	(284)
	-100	0.1627			ZnCO <sub>3</sub>	0 to 260	0.593 + 0.02193t	3	(147)
	0	0.1744			Zn(C <sub>2</sub> H <sub>3</sub> O <sub>2</sub> ) <sub>2</sub>	45	1.13	2	(114)
	+100	0.183	1		Zn(C <sub>2</sub> H <sub>3</sub> O <sub>2</sub> ) <sub>2</sub> .3H <sub>2</sub> O	85	1.71	2	(114)
	200	0.197			2CdCl <sub>2</sub> .5H <sub>2</sub> O	-200 to 20	1.019 + 0.00350t	4	(277)
	250	0.204			CdS	-150	0.227	0.5	(262)
PbS	-220	0.118	5	(39, 76, 117, 132, 147, 199, 240, 255, 287, 299)		-100	0.301		
	-200	0.144	2			0	0.369		
	-150	0.176				+ 50	0.386		
	-100	0.194	1		3CdSO <sub>4</sub> .8H <sub>2</sub> O	-200	0.259	5	(58, 89, 134, 135, 277)
	-50	0.205				-150	0.481	10	
	0	0.210				-100	0.636		
	+100	0.214	2			-50	0.749	4	
	200	0.217				0	0.816	2	
	400	0.227	4			+ 20	0.836	0.5	
	450	0.233	6		Cd(NO <sub>3</sub> ) <sub>2</sub> .4H <sub>2</sub> O	40	1.09	1	(284)
PbSO <sub>4</sub>	45	0.351	3	(137, 240)	HgO	-250	0.0347	1	(196, 137, 240, 263)
PbS <sub>2</sub> O <sub>3</sub>	58	0.384	2	(217)		-225	0.0620	0.5	
Pb(NO <sub>3</sub> ) <sub>2</sub>	45	0.481	1	(137, 199)		-200	0.1087		
2PbCl <sub>2</sub> .NH <sub>4</sub> Cl	10	0.362	1	(48)		-100	0.165		
PbP <sub>2</sub> O <sub>7</sub>	55	0.343	2	(240)		0	0.203		
Pb <sub>2</sub> As <sub>2</sub> O <sub>7</sub>	55	0.305	2	(240)		+ 50	0.218		
PbCO <sub>3</sub>	32	0.335	2	(137)	HgCl	-250	0.0556	0.5	(48, 82, 106, 235, 236, 240)
PbSiO <sub>3</sub>	60	0.326	1	(274)		-200	0.1430		
ThO <sub>2</sub>	-150	0.128	1	(67, 262, 263)		-150	0.1740	0.25	
	-100	0.175				-100	0.1892		
	-50	0.212				0	0.2087	0.25	
						50	0.2141		



Substance	$t$ or $\Delta t$ , °C	$c_p$ , joule/g	$\pm$ %	Lit.	Substance	$t$ or $\Delta t$ , °C	$c_p$ , joule/g	$\pm$ %	Lit.
HgCl <sub>2</sub> .....	-150	0.203	1	(86, 127, 240)	2CuO.CO <sub>2</sub> .H <sub>2</sub> O, Malachite.....	57	0.74	2	(204)
	-100	0.235	0.5		CuPbSbS <sub>2</sub> , Bour- nonite.....	50	0.31	5	(278)
	-50	0.257			AgCl.....	-260	0.037	6	(48, 67, 78, 82, 86, 98, 169, 194, 198, 240)
	0	0.268				-240	0.143	2	
HgBr <sub>2</sub> .....	+100	0.280				-220	0.231	0.5	
HgI.....	100	0.217	3	(109)		-200	0.2655		
HgI <sub>2</sub> (red).....	-120 to +100	0.1498 + 0.04654	2	(86, 240)		-100	0.331	0.25	
	-150	0.147	1	(13, 86, 108, 109, 240)		-50	0.351		
	-100	0.159	0.5			0	0.355		
	0	0.169				+50	0.379		
	+50	0.173				100	0.3885	0.5	
(yellow).....	206	0.167	10	(108, 109)		200	0.408		
HgS.....	-150	0.135	1	(137, 240, 262)		300	0.414	1	
	-100	0.178	0.5			400	0.421		
	-50	0.200				500	0.423		
	0	0.2116	0.25		AgBr.....	-100	0.261	2	(67, 98, 240)
	+50	0.2175				-50	0.265		
	100	0.2187				0	0.291	1	
Hg <sub>2</sub> SO <sub>4</sub> .....	-250	0.0452	1	(58, 235, 236, 270, 271)		+100	0.307		
	-200	0.1087	0.5			200	0.312	2	
	-150	0.1713	0.25			400	0.318		
	-100	0.2032			AgI.....	-260	0.043	4	(25, 67, 86, 128, 169, 193, 194, 198, 240)
	0	0.2580				-240	0.102	2	
	+50	0.2844	0.25			-220	0.140	1	
Hg(CN) <sub>2</sub> .....	29	0.42	3	(137)		-200	0.1706		
CuO.....	-200	0.144	0.25	(137, 169, 240, 262)		-150	0.2028	0.5	
	-100	0.376				-100	0.2120		
	0	0.523				-50	0.2175	0.25	
	+100	0.602				0	0.2292		
	200	0.648				+100	0.248	1	
	400	0.669				-150	0.196	1	(24, 255, 278)
	600	0.677				-100	0.251		
Cu <sub>2</sub> O.....	0	0.460	1	(137, 169)		0	0.301		
	100	0.485				+50	0.313		
	200	0.506				100	0.318		
	300	0.523				150	0.35		
	400	0.535				37 to 187	0.29	3	(24)
CuCl <sub>2</sub> .....	58	0.58	2	(240)	Ag <sub>2</sub> Se.....	50	0.61	4	(109, 240)
CuI.....	-260	0.0226	0.25	(86, 240, 262)	AgNO <sub>3</sub> .....	160U			
	-230	0.1217				178	0.65		(108, 109)
	-200	0.1907				192	0.82	4	(98)
	-150	0.2350				50	0.34	3	(278)
	-100	0.2543			Ag <sub>2</sub> AsS <sub>3</sub> , Proustite..	50			
	-50	0.2668			Ag <sub>2</sub> SbS <sub>3</sub> , Pyrargy- rite.....	50	0.32	3	(278)
	0	0.2752				-150 to 20	0.586 + 0.002304	2	(68)
	+50	0.2810			AgCN.....	40	0.52	2	(211)
CuS.....	-150	0.32	6	(29, 262)	AgCNO.....	40	0.410	2	(211)
	-75	0.43	4		(AgCNO) <sub>2</sub> .....	40		2	(25)
	0	0.54	2		AgI.PbI <sub>2</sub> .....	50 to 250	0.182 + 0.0001144	2	(180)
	+100	0.63			AuI.....	-100	0.148	2	
	200	0.72	4			-50	0.157	1	
	300	0.67	5			0	0.169		
	400	0.61	6			+50	0.181		
	500	0.56	6		MnO.....	58	0.66	2	(137)
	600	0.52	5		MnO <sub>2</sub> .....	-150	0.355	1	(137, 262)
	800	0.48	5			-100	0.480	0.5	
Cu <sub>2</sub> S.....	0 to 100	0.449 + 0.001104	2	(24, 240)		-50	0.573		
	104U					0	0.636		
CuSO <sub>4</sub> .....	190	0.61	2	(24)		+50	0.682		
	-150	0.328	0.5	(86, 128, 198, 216, 270, 279)		100	0.703	1	
	-50	0.587			Mn <sub>2</sub> O <sub>3</sub> .....	58	0.68	2	(204)
	0	0.618			Mn <sub>2</sub> O <sub>3</sub> .3H <sub>2</sub> O.....	38	0.74	2	(137)
CuSO <sub>4</sub> .H <sub>2</sub> O.....	+50	0.694			MnS.....	60	0.58	2	(278)
	-150	0.396	0.5	(86, 198, 270, 279)	MnSO <sub>4</sub> .....	61	0.76	2	(210)
	-50	0.647			MnSO <sub>4</sub> .5H <sub>2</sub> O.....	32	1.35	2	(137)
	0	0.719			Mn(NO <sub>3</sub> ) <sub>2</sub> .6H <sub>2</sub> O....	47	1.56	2	(254)
	+50	0.798			Fe <sub>2</sub> O <sub>3</sub> .....	-180	0.171	2	(50, 226, 240, 262)
CuSO <sub>4</sub> .3H <sub>2</sub> O.....	9	0.956		(270)		-100	0.410		
CuSO <sub>4</sub> .5H <sub>2</sub> O.....	-150	0.648	2	(86, 128, 137, 240, 270, 279, 282)		0	0.618		
	-100	0.790				+100	0.76		
	-50	0.924				200	0.85		
	0	1.058				300	0.94		
	+50	1.200				350	0.98		
Cu <sub>2</sub> Se.....	60	0.437	2	(24)		360	U		
	110U					370	1.06		
	200	0.437	2			400	1.10		
CuSO <sub>4</sub> (NH <sub>4</sub> ) <sub>2</sub> SO <sub>4</sub> . 6H <sub>2</sub> O.....	-150	0.85	2	(128)		500	1.23		
	-75	0.97				600	1.36		
	0	1.07				700	1.49		



Substance	$t$ or $\Delta t$ , °C	$c_p$ , joule/g	$\pm$ %	Lit.
$2\text{Fe}_2\text{O}_3 \cdot 3\text{H}_2\text{O}$ , Limonite.....	60	0.94	2	(132)
$\text{Fe}_2\text{O}_3$ .....	-200	0.14	10	(220, 240, 314)
	-100	0.45	5	
	0	0.63		
	+100	0.75		
	200	0.85		
	300	0.93		
	400	1.00		
	500	1.07		
	550	1.11		
$\text{FeS}$ .....	0 to 700	$0.567 + 0.00065t$	2	(39, 240)
$\text{FeS}_2$ .....	-280	0.0042	3	(85, 86, 117, 132, 137, 138, 199, 240, 299)
	-225	0.0197	2	
	-200	0.075		
	-150	0.222	1	
	-100	0.352	0.5	
	-50	0.483		
	0	0.493		
	+50	0.535		
	100	0.569	1	
	150	0.615	1.5	
$\text{Fe}_7\text{S}_8$ , Magnetic pyrites.....	0	0.594	2	(117, 147, 199)
	100	0.657		
	200	0.77	3	
	300	0.96		
	350	1.11	4	
$\text{FeSO}_4$ .....	45	0.70	3	(202)
$\text{FeSO}_4 \cdot 4\text{H}_2\text{O}$ .....	9	1.19	2	(256)
$\text{FeSO}_4 \cdot 7\text{H}_2\text{O}$ .....	-150	0.67	2	(125, 137, 256)
	-100	0.90		
	-50	1.12	1	
	0	1.36		
	+10	1.41		
$\text{FeAsS}$ .....	55	0.47	10	(204, 278)
$\text{FeAs}_2$ .....	50	0.36	3	(278)
$\text{FeCO}_3$ .....	54	0.81	2	(240)
$\text{Fe}_2(\text{SiO}_3)_3$ .....	59	0.80	2	(305)
$\text{FeCuS}_2$ , Chalcopyrite.....	48	0.54	2	(132, 137, 204)
$\text{FeCu}_3\text{S}_4$ .....	48	0.49	2	(278)
$\text{CoSO}_4 \cdot 7\text{H}_2\text{O}$ .....	48	1.43	2	(137)
$\text{Co}(\text{NO}_3)_2 \cdot 6\text{H}_2\text{O}$ .....	32	1.56	0.5	(254)
$\text{CoAsS}$ , Cobaltite.....	58	0.41	2	(204, 278)
$\text{NiS}$ .....	-100	0.372	3	(298)
	0	0.485	2	
	+100	0.537		
	200	0.577		
	225	0.583		
$\text{NiSO}_4$ .....	58	0.90	2	(216)
$\text{NiSO}_4 \cdot 6\text{H}_2\text{O}$ .....	35	1.31	2	(137)
$\text{Ni}(\text{NO}_3)_2 \cdot 6\text{H}_2\text{O}$ .....	80	1.98	0.5	(254)
$\text{Ni}(\text{CO})_4$ .....	-78 to -188	0.69	3	(88)
$\text{FeCoNiAs}_2$ .....	50	0.35	3	(278)
$\text{Cr}_2\text{O}_3$ .....	-200	0.111	2	(137, 240, 262)
	-100	0.414	1	
	0	0.703		
	+50	0.790		
$\text{Cr}_2(\text{SO}_4)_3$ .....	50	0.72	2	(202)
$\text{Cr}_2(\text{SO}_4)_3 \cdot 5\text{H}_2\text{O}$ .....	50	0.836	2	(202)
$\text{PbCrO}_4$ .....	35	0.38	2	(137)
$\text{MoO}_3$ .....	54	0.56	2	(240)
$\text{WO}_3$ .....	-150	0.15	2	(240, 262)
	-100	0.222	1	
	0	0.311		
	+50	0.348		
$3\text{MnWO}_4 \cdot 2\text{FeWO}_4$ .....	0 to 300	$0.41 + 0.00007t$	3	(147)
$\text{U}_2\text{O}_5$ .....	-150	0.164	1	(262)
	-100	0.206		
	0	0.281		
	+50	0.314		
$\text{Cb}_2\text{O}_5$ .....	50 to 450	$0.423 + 0.00064t$	2	(201)
$\text{B}_2\text{O}_3$ (vitreous).....	-250 to 200	$0.805 + 0.0023st$	3	(84, 240, 262)
$\text{PbB}_2\text{O}_4$ .....	57	0.378	2	(240)
$\text{PbB}_4\text{O}_7$ .....	57	0.47	2	(240)
$\text{PbMoO}_4$ .....	15	0.42	2	(85.5)
$\text{PbWO}_4$ .....	15	0.322	2	(85.5)

Substance	$t$ or $\Delta t$ , °C	$c_p$ , joule/g	$\pm$ %	Lit.
$\text{BN}$ .....	200	1.46	2	(172)
	400	1.80		
	600	2.06	4	
	800	2.28		
	900	2.36		
$\text{Al}_2\text{O}_3$ , Corundum, sapphire, etc.....	-200	0.069	1	(40, 85, 132, 202, 220, 234, 240, 262, 311)
	-150	0.225		
	-100	0.415		
	-50	0.598		
	0	0.73		
	+50	0.83	3	
	100	0.89	5	
	200	0.97		
	400	1.07		
	600	1.12		
	800	1.15		
	1000	1.17		
$\text{Al}(\text{OH})_3$ .....	-200	0.146	1	(132, 202, 234, 240, 262, 311)
	-100	0.433	1	
	0	0.740	0.5	
	+50	0.845		
	100	0.899		
	200	0.962	1	
	300	0.995		
	400	1.012	2	
	600	1.029		
	800	1.034	3	
	900	1.096	4	
	1000	1.150	6	
	1100	1.255	6	
$\text{AlF}_3$ .....	35	0.96	2	(32)
$2\text{AlF}_3 \cdot 7\text{H}_2\text{O}$ .....	35	1.43	2	(32)
$\text{AlCl}_3$ (a).....	93	1.96	2	(304)
( $\beta$ ).....	0	0.82	2	(32, 264)
	100	1.52		
$\text{AlCl}_3 \cdot 6\text{H}_2\text{O}$ .....	35	1.31	2	(22, 290)
$\text{AlCl}_3 \cdot 6\text{NH}_3$ .....	-4	1.67	2	(32)
$\text{Al}_2(\text{SO}_4)_3$ .....	50	0.77	2	(202)
$\text{Al}_2(\text{SO}_4)_3 \cdot 17\text{H}_2\text{O}$ .....	34	1.48	1	(22)
$\text{Al}_2\text{C}_2\text{O}_7 \cdot 18\text{H}_2\text{O}$ , Mellite.....	52	1.39	2	(16)
$\text{Al}_2\text{SiO}_5$ , v. p. 101. 2( $\text{AlF}$ ) $\text{O}_2\text{SiO}_2$ , Topaz.....	52	0.86	1	(132, 147)
$\text{Sc}_2\text{O}_3$ .....	-150 to 40	$0.701 + 0.00275t$	1	(202, 262)
$\text{Y}_2\text{O}_3$ .....	57	0.468	1	(202)
$\text{La}_2\text{O}_3$ .....	50	0.314	2	(202)
$\text{La}_2(\text{MoO}_4)_3$ .....	15	0.48	2	(85.5)
$\text{CeO}_2$ .....	-150	0.177	0.5	(202, 262)
	-100	0.251		
	-50	0.309		
	0	0.364		
	+50	0.397		
$\text{CeSO}_4$ .....	50	0.49	3	(202)
$\text{CeSO}_4 \cdot 5\text{H}_2\text{O}$ .....	50	0.84	3	(202)
$\text{Ce}_2(\text{MoO}_4)_3$ .....	15	0.53	2	(85.5)
$\text{Ga}_2\text{O}_3$ .....	50	0.44	2	(202)
$\text{Er}_2\text{O}_3$ .....	50	0.272	2	(202)
$\text{Yb}_2\text{O}_3$ .....	50	0.272	2	(202)
$\text{BeO}$ .....	-200	0.029	3	(106)
	-190	0.043		
	-180	0.065		
	+50	1.09	2	(172, 202)
	100	1.25		
	200	1.47		
	400	1.76		
	600	1.93		
	800	2.04		
	900	2.08		
$\text{BeSO}_4$ .....	50	0.83	2	(202)
$\text{Al}_2\text{BeO}_4$ , Chrysoberyl.....	50	0.84	3	(202)
$\text{Y}_2(\text{MoO}_4)_3$ .....	15	0.87	2	(85.5)
$3\text{BeO} \cdot \text{Al}_2\text{O}_3 \cdot 6\text{SiO}_2$ , Beryl.....	57	0.84	2	(132, 204)
$\text{MgO}$ .....	-240	0.0027	3	(106)
	-220	0.0146		
	-200	0.066	2	
	-180	0.157		
	-150	0.314		



Substance	$t$ or $\Delta t$ , °C	$c_p$ , joule/g	$\pm$ %	Lit.
MgO.—(Cont'd)....	-100	0.54		(170, 220, 240, 262)
	- 50	0.74		
	0	0.874		
	+ 50	0.97	1	
	100	1.02		
	200	1.09		
	400	1.16		
	600	1.22		
	800	1.28		
	1000	1.35	3	
	1500	1.49	5	(311)
	2000	1.62		
	2500	1.78	10	
MgO.H <sub>2</sub> O, Brucite..	35	1.30	2	(137)
MgCl <sub>2</sub> .....	48	0.81	1	(137, 240)
MgCl <sub>2</sub> .6H <sub>2</sub> O.....	44	1.58	1	(254)
MgSO <sub>4</sub> .....	61	0.93	1	(216, 240)
MgSO <sub>4</sub> .H <sub>2</sub> O.....	9	1.00	2	(256)
MgSO <sub>4</sub> .6H <sub>2</sub> O.....	9	1.46	2	(256)
MgSO <sub>4</sub> .7H <sub>2</sub> O.....	12	1.51	1	(137, 256)
Mg(NO <sub>3</sub> ) <sub>2</sub> .6H <sub>2</sub> O....	55	3.71	1	(254)
MgCO <sub>3</sub> .....	25	0.838	0.5	(184)
Mg <sub>3</sub> Si <sub>4</sub> O <sub>11</sub> .H <sub>2</sub> O, Talc.....	57	0.87	2	(204)
6MgO.MgCl <sub>2</sub> . 8B <sub>2</sub> O <sub>3</sub> , Boracite (hexahedral)....	-50 to 350	0.753 + 0.0025434	4	(140)
(dodecahedral)...	50	0.90	2	(140)
	100	1.00		
	200	1.22		
	250	1.37	5	
	265U			
	300	1.69		
CaO.....	-240	0.011	7	(86, 138, 142, 170, 198, 198, 220, 311)
	-220	0.053	6	
	-200	0.142	2	
	-150	0.368		
	-100	0.54		
	- 50	0.66		
	0	0.74	1	
	+100	0.824		
	200	0.857		
	400	0.882	2	
	600	0.91		
	800	0.92	4	
	1000	0.94		
	1200	0.95		
CaH <sub>2</sub> .....	-210	0.141	3	(108)
	-200	0.195		
Ca(OH) <sub>2</sub> .....	-180	0.302		
	-250	0.029	3	(86, 138, 198)
	-200	0.205	2	
	-150	0.510	1	
	-100	0.765	0.5	
	- 50	0.949		
	0	1.087		
CaF <sub>2</sub> .....	+ 50	1.204		
	-250	0.0117	4	(88, 132, 137, 138, 199, 240)
	-200	0.218	3	
	-150	0.470	0.5	
	-100	0.640	0.25	
	- 50	0.803		
	0	0.854		
	+ 40	0.887		
	80	0.907		
CaCl <sub>2</sub> .....	61	0.686	2	(240)
CaCl <sub>2</sub> .6H <sub>2</sub> O.....	-150	0.91	5	(67, 228)
	- 75	1.18	4	
	0	1.34		
CaSO <sub>4</sub> .2H <sub>2</sub> O.....	9	1.14	1	(34)
CaSO <sub>4</sub> .....	0 to 400	0.7084 + 0.0006094	1 to 3	(137, 147, 240, 312)
CaSO <sub>4</sub> .2H <sub>2</sub> O.....	36	1.11	1	(132, 137, 199, 312)
Ca(PO <sub>3</sub> ) <sub>2</sub> .....	-260	0.00530	0.5	(108)
	-240	0.01212		
	-220	0.0432		
	-200	0.1018		
	-100	0.563	10	(108, 240)
	0	0.795	6	
	+ 50	0.828	2	



Substance	$t$ or $\Delta t$ , °C	$c_p$ , joule/g	$\pm$ %	Lit.	Substance	$t$ or $\Delta t$ , °C	$c_p$ , joule/g	$\pm$ %	Lit.
BaCO <sub>3</sub> .....	0	0.418	2	(132, 199, 240)	Na <sub>2</sub> HPO <sub>4</sub> ·12H <sub>2</sub> O...	-200	0.50	2	(193, 194, 195, 225)
	100	0.460				-100	1.12	1	
	200	0.485	2			0	1.69		
	400	0.514				+50	1.94		
	600	0.539	3		Na <sub>2</sub> CO <sub>3</sub> .....	45	1.07	2	(137, 240)
	800	0.544			NaHCO <sub>3</sub> , Formate.	46	1.28	1	(114, 212)
BaCO <sub>3</sub> , Witherite..	800	0.581	3	(142)	NaC <sub>2</sub> H <sub>3</sub> O <sub>2</sub> , Acetate.	38	1.42	4	(96, 212)
	900	0.657			NaC <sub>2</sub> H <sub>3</sub> O <sub>2</sub> ·3H <sub>2</sub> O...	0	1.44	5	(96)
	1000	0.673				10	1.72		
Ba(CHO <sub>2</sub> ) <sub>2</sub> , Formate.....	0 to 120	0.572 + 0.00060t	1 to 2	(114)		20	1.98		
BaMoO <sub>4</sub> .....	15	0.47	2	(55.5)		40	2.52		
LiH.....	-200	0.341	0.5	(107)	NaCNO.....	40	0.84	2	(211)
	-180	0.667			(NaCNO) <sub>2</sub> .....	40	0.69	2	(211)
	-160	1.18	2		Na <sub>2</sub> SO <sub>4</sub> ·CuSO <sub>4</sub> · 6H <sub>2</sub> O.....	-150	0.437	2	(128)
	-80	3.06				-100	0.611	1	
	0	4.10	0.5			0	0.824	0.5	
LiOH.....	+50	4.48			Na <sub>2</sub> B <sub>4</sub> O <sub>7</sub> .....	57	1.06	2	(240)
	-210	0.079	5	(107)	Na <sub>2</sub> B <sub>4</sub> O <sub>7</sub> ·10H <sub>2</sub> O, Borax.....	45	0.98	2	(137, 240)
	-200	0.119	3			35	1.61	3	(137)
	-190	0.164	1		3NaF·AlF <sub>3</sub> , Cryolite.....	43	1.054	0.5	(22, 132, 137, 204)
	-180	0.224			Na <sub>2</sub> O·Al <sub>2</sub> O <sub>3</sub> ·6SiO <sub>2</sub> , Albite.....	-50	0.640	2	(204, 318)
	-170	0.295				0	0.745		
	-100	0.88	5			+100	0.887		
	0	1.37	1			200	0.991		
LiF.....	+50	1.49				300	1.058		
LiCl.....	10	1.56	1	(49)		400	1.096		
Li <sub>2</sub> SiO <sub>3</sub> .....	55	1.18	2	(245)		600	1.154		
Li <sub>2</sub> SO <sub>3</sub> .....	58	0.385	2	(217)		800	1.200		
LiNO <sub>3</sub> .....	210	1.62	2	(98)		1000	1.240		
Li <sub>2</sub> O·Al <sub>2</sub> O <sub>3</sub> ·4SiO <sub>2</sub> , Spodumene.....	60	0.90	3	(274)	3(NaAlSi <sub>3</sub> O <sub>8</sub> ) + 2(CaAl <sub>2</sub> Si <sub>2</sub> O <sub>7</sub> ), Andesine.....	0	0.75	5	(204, 318)
Li <sub>2</sub> O·Al <sub>2</sub> O <sub>3</sub> ·8SiO <sub>2</sub> , Petalite.....	58	0.85	2	(204)		100	0.86		
NaF.....	-150	0.675	2	(49, 138)		200	0.95		
	-100	0.886				400	1.08	2	
	-50	1.013	0.25			600	1.13		
	0	1.080				800	1.17		
NaCl.....	+100	1.167				1000	1.19		
	-250	0.021	10	(49, 67, 138, 146, 170, 194, 196, 197, 240, 262)	K <sub>2</sub> O <sub>2</sub> .....	200 to 700	0.833 + 0.000116t	1	(170)
	-200	0.466	1		KF.....	-150	0.602	1	(49, 138)
	-150	0.657	0.5			-100	0.727	0.5	
	-100	0.736				-50	0.799		
	0	0.853				0	0.831		
	+100	0.908	1		KCl.....	+50	0.853		
	200	0.924	2			-250	0.069	1	(49, 137, 138, 146, 170, 194, 196, 197, 198, 240, 262)
	400	0.96	4			-200	0.448	0.5	
	500	0.97				-150	0.588		
NaBr.....	600	0.99				-100	0.634		
	-150	0.408	0.5	(49, 138, 170, 240, 272)		-50	0.664		
	-100	0.450				0	0.680		
	0	0.492				+100	0.703		
	+100	0.518	1			200	0.721	1	
NaI.....	200	0.527				400	0.749	2	
	-150	0.302	1	(49, 138, 240, 272)	KClO <sub>3</sub> .....	-150	0.500	2	(86, 98, 137, 240)
	-100	0.324				-100	0.644	1	
	0	0.347				0	0.799		
Na <sub>2</sub> SO <sub>4</sub> .....	+50	0.355				+50	0.857		
	-200	0.315	0.5	(86, 128, 240, 272)		100	0.970	1	
	-150	0.503				200	1.238	2	
	-100	0.654				225	1.355	3	
	-50	0.770			KClO <sub>4</sub> .....	30	0.79	3	(137)
	0	0.846			KBr.....	-200	0.3254	0.5	(49, 86, 138, 170, 194, 240)
Na <sub>2</sub> S <sub>2</sub> O <sub>3</sub> .....	+100	0.919				-100	0.4027		
Na <sub>2</sub> S <sub>2</sub> O <sub>3</sub> ·5H <sub>2</sub> O.....	9	0.92	1	(217, 271)		0	0.435		
NaNO <sub>3</sub> .....	21	1.45	3	(271, 292)		+100	0.452		
	-150	0.627	0.5	(86, 98, 240, 272)		200	0.460		
	-100	0.807				300	0.463		
	-50	0.937			KI.....	-140 to 80	0.3124 + 0.000230t	1	(49, 128, 195, 240)
	0	1.035							
	+50	1.129			K <sub>2</sub> SO <sub>4</sub> .....	-150	0.473	1	(86, 128, 137, 240)
	100	1.23	1			-100	0.577		
	200	1.38	2			0	0.736		
	250	1.50	4			+100	0.799		
NaPO <sub>3</sub> .....	30	0.91	2	(137)	K <sub>2</sub> S <sub>2</sub> O <sub>8</sub> .....	60	0.82	2	(217)
Na <sub>2</sub> P <sub>2</sub> O <sub>7</sub> .....	50	0.95	2	(240)	KHSO <sub>4</sub> .....	35	1.02	2	(137)
Na <sub>2</sub> HPO <sub>4</sub> ·7H <sub>2</sub> O.....	-200	0.50	2	(193, 195)	KNO <sub>3</sub> .....	-150	0.579	0.5	(86, 98, 137, 240)
	-100	1.03	1			-100	0.740		
	0	1.47							
	+50	1.70							



Substance	$t$ or $\Delta t$ , °C	$c_p$ , joule/g	$\pm$ %	Lit.
$\text{KNO}_3$ —(Cont'd)...	0	0.895		
	+100	1.004	1	
	200	1.117		
	300	1.22	2	
$\text{K}_2\text{P}_2\text{O}_7$ .....	58	0.80	2	(240)
$\text{KH}_2\text{PO}_4$ .....	33	0.87	3	(137)
$\text{KAsO}_2$ .....	58	0.65	2	(240)
$\text{KH}_2\text{AsO}_4$ .....	31	0.73	2	(137)
$\text{K}_2\text{CO}_3$ .....	47	0.88	1	(137, 240)
$\text{K}_2\text{C}_2\text{O}_4 \cdot \text{H}_2\text{O}$ .....	-100	0.70	1.5	(90, 137)
	-60	0.85		
	-20	0.93		
	+20	0.97		
$\text{KC}_2\text{H}_3\text{O}_2$ .....	20	1.14	2	(114)
	40	1.74		
	60	2.20		
	80	2.63		
	100	2.90		
$\text{KH}_2\text{C}_2\text{O}_4 \cdot 2\text{H}_2\text{O}$ .....	35	1.18	2	(137)
$\text{K}(d\text{-C}_4\text{H}_5\text{O}_6)$ .....	10	0.97	1	(48)
$\text{K}(dl\text{-C}_4\text{H}_5\text{O}_6)$ .....	10	0.98	1	(48)
$\text{K}_2\text{C}_2\text{H}_4\text{O}_4$ .....	35	1.07	2	(137)
$\text{K}_2\text{SnCl}_6$ .....	35	0.56	2	(137)
$\text{K}_2\text{ZnCl}_4$ .....	32	0.64	2	(137)
$\text{K}_2\text{SO}_4 \cdot \text{ZnSO}_4 \cdot 6\text{H}_2\text{O}$ .....	-150	0.49	2	(125)
	-100	0.65		
	0	0.81		
$\text{K}_2\text{Zn}(\text{CN})_4$ .....	30	1.01	2	(137)
$\text{K}_2\text{CuCl}_4 \cdot 2\text{H}_2\text{O}$ .....	35	0.82	2	(137)
$\text{K}_2\text{PtCl}_6$ .....	30	0.47	2	(137)
$\text{K}_4\text{Fe}(\text{CN})_6$ .....	26	0.97	2	(137)
$\text{K}_4\text{Fe}(\text{CN})_6$ .....	-200	0.397	3	(193, 194,
	-150	0.544		195, 270,
	-100	0.604	2	271)
	0	0.878	1	
	-50	0.941		
$\text{K}_4\text{Fe}(\text{CN})_6 \cdot 3\text{H}_2\text{O}$ .....	-200	0.464	3	(193, 194,
	-150	0.757	1	195, 270,
	-100	0.937	0.5	271)
	0	1.118		
	+50	1.192		
$\text{K}_2\text{SO}_4 \cdot \text{NiSO}_4 \cdot 6\text{H}_2\text{O}$ .....	31	1.02	2	(137)
$\text{K}_2\text{CrO}_4$ .....	46	0.78	2	(137, 240)
$\text{K}_2\text{Cr}_2\text{O}_7$ .....	0 to 400	0.746 + 0.000602t	2	(98, 137,
				240)
$\text{K}_2\text{SO}_4 \cdot \text{Cr}_2(\text{SO}_4)_3 \cdot 24\text{H}_2\text{O}$ .....	-150	0.81	5	(67, 137)
	-100	0.92		
	0	1.08		
	+100	1.23		
$\text{K}_2\text{B}_2\text{O}_7$ .....	57	0.94	2	(240)
$\text{K}_2\text{B}_4\text{O}_7$ .....	57	0.92	2	(240)
$\text{K}_2\text{SO}_4 \cdot \text{Al}_2(\text{SO}_4)_3 \cdot 24\text{H}_2\text{O}$ .....	-250	0.089	1	(22, 67, 198)
	-200	0.560		
	-150	0.862		
	-100	1.058		
	0	1.355		
	+50	1.506		

Substance	$t$ or $\Delta t$ , °C	$c_p$ , joule/g	$\pm$ %	Lit.
$\text{K}_2\text{O} \cdot \text{Al}_2\text{O}_3 \cdot 6\text{SiO}_2$ , Microcline.....	0	15.2*	0.5	(318)
	100	17.9		
	200	19.7		
	400	22.3	1	
	800	24.3		
	1000	24.8		
$\text{K}_2\text{O} \cdot \text{Al}_2\text{O}_3 \cdot 6\text{SiO}_2$ , Orthoclase.....	100	0.86	1	(204, 316)
	200	0.92		
	400	1.03		
	600	1.11		
	800	1.14		
	1000	1.17		
	1100	1.19		
$\text{K}_2\text{O} \cdot \text{Al}_2\text{O}_3 \cdot 6\text{SiO}_2$ , Adular.....	0	0.732		(147, 199,
	100	0.799	2	204, 274)
	200	0.842		
	300	0.937		
	400	1.000		
$\text{K}_2\text{SO}_4 \cdot \text{MgSO}_4 \cdot 6\text{H}_2\text{O}$ .....	35	1.10	2	(137)
$\text{KNaC}_4\text{H}_4\text{O}_6 \cdot 4\text{H}_2\text{O}$ .....	35	1.37	2	(137)
$\text{RbF}$ .....	10	0.482	1	(49)
$\text{RbCl}$ .....	10	0.424	1	(49, 137)
$\text{RbBr}$ .....	10	0.311	1	(49)
$\text{RbI}$ .....	10	0.243	1	(49)
$\text{Rb}_2\text{CO}_3$ .....	33	0.51	5	(137)
$\text{CsF}$ .....	10	0.333	1	(49)
$\text{CsCl}$ .....	10	0.312	1	(49)
$\text{CsBr}$ .....	10	0.243	1	(49)
$\text{CsI}$ .....	10	0.200	1	(49)

$\text{Al}_2\text{SiO}_5$ ,  $c_p$ , joule/g  $\pm 2\%$  (60, 147, 200)

$t$ , °C	Cyanite	Andalusite	Sillimanite
-250	0.0025	0.012	0.010
-200	0.0775	0.152	0.133
-150	0.245	0.331	0.303
-100	0.425	0.481	0.470
0	0.708	0.770	0.722
+100	0.874	0.954	0.875
200	0.983	1.07	0.994
300	1.050	1.13	1.075
400	1.096	1.17	1.125
600	1.16	1.17	1.16
800	1.19	1.17	1.17
1000	1.23	1.17	1.17
1100	1.24	1.175	1.17
1200	1.25	1.175	1.17

\* Molecular heat/number of atoms in molecule.

C-TABLE, C-ARRANGEMENT (v. Vol. III, p. viii)

Formula	Name	$t$ , °C	$c_p$ , joule/g	$\pm$ %	Lit.
$\text{CCl}_4$	Carbon tetrachloride.....	-240	0.055	5	(143)
		-200	0.340	2	
		-160	0.55		
		-120	0.68		
		-80	0.76		
		-40	0.84		
$\text{CH}_3\text{N}_3$	Cyanamide.....	20	2.29	2	(211)
$\text{CH}_2\text{O}_2$	Formic acid.....	-22	1.62	3	(177)
		0	1.80		
$\text{CH}_4$	v. p. 86.				
$\text{CH}_4\text{N}_2\text{O}$	Urea.....	20	1.34	1	(166)
$\text{C}_2\text{Cl}_4$	Tetrachloroethylene.....	-40 to 0	0.828 + 0.00075t	3	(240)
$\text{C}_2\text{Cl}_6$	Hexachloroethane.....	25	0.73	2	(137)
$\text{C}_2\text{HCl}_3\text{O}_2$	Trichloroacetic acid.....	solid	1.92	3	(233)



Formula	Name	$t, ^\circ\text{C}$	$c_p$ , joule/g	$\pm \%$	Lit.
$\text{C}_2\text{H}_2\text{Cl}_2\text{O}_2$	Dichloroacetic acid.....	solid	1.70	2	(233)
$\text{C}_2\text{H}_2\text{O}_4$	Oxalic acid.....	-200 to 50	$1.084 + 0.00319t$	0.5	(194, 195)
$\text{C}_2\text{H}_2\text{O}_4 \cdot 2\text{H}_2\text{O}$	Oxalic acid.....	-200	0.489	1	(120, 194, 195)
		-100	1.000	0.5	
		0	1.414		
		+ 50	1.61	1	
		100	1.74		
$\text{C}_2\text{H}_3\text{ClO}_2$	Chloroacetic acid.....	60	1.52	2	(233)
$\text{C}_2\text{H}_3\text{Cl}_3\text{O}_2$	Chloral hydrate.....	32	0.89	1	(27, 258)
$\text{C}_2\text{H}_4\text{N}_4$	Dicyandiamide.....	0 to 204	1.91	1	(211)
$\text{C}_2\text{H}_4\text{O}_2$	Acetic acid.....	-200 to +25	$1.382 + 0.00336t$	2	(68, 86, 92, 105, 178, 219)
$\text{C}_2\text{H}_6\text{O}$	Ethyl alcohol (crystalline).....	-190	0.970	0.5	(95)
		-180	1.037		
		-160	1.179		
		-140	1.330		
		-130	1.572		
	(vitreous).....	-190	1.09	1	(95)
		-180	1.24		
		-175	1.59		
		-170	1.67		
$\text{C}_2\text{H}_6\text{O}_2$	Glycol.....	-190 to -40	$1.53 + 0.00459t$	2	(219, 306)
$\text{C}_3\text{H}_3\text{N}_3\text{O}_3$	Cyamelide.....	40	1.10	2	(211)
$\text{C}_3\text{H}_3\text{N}_3\text{O}_3$	Cyanuric acid.....	40	1.33	2	(211)
$\text{C}_3\text{H}_4\text{O}_4$	Malonic acid.....	20	1.15	2	(120)
$\text{C}_3\text{H}_6\text{N}_6$	Melamine.....	40	1.47	2	(211)
$\text{C}_3\text{H}_6\text{O}$	Acetone.....	-210 to -80	$2.260 + 0.0655t$	2	(219)
$\text{C}_3\text{H}_6\text{O}_2$	Propionic acid.....	-33	3.04	2	(177)
$\text{C}_3\text{H}_8\text{O}$	<i>n</i> -Propyl alcohol.....	-200	0.71	3	(95)
		-175	1.52		
		-150	1.97		
		-130	2.08		
$\text{C}_3\text{H}_8\text{O}_2$	Isopropyl alcohol.....	-200 to -160	$0.212 + 0.0069t$		(219)
$\text{C}_3\text{H}_8\text{O}_3$	Glycerol.....	-265	0.038	10	(93, 282, 283)
		-260	0.090		
		-250	0.197		
		-220	0.355	4	
		-200	0.48		
		-100	0.91	2	
		0	1.38		
$\text{C}_4\text{H}_6\text{O}_2$	Crotonic acid.....	38 to 70	$2.178 - 0.000825t$	2	(159)
$\text{C}_4\text{H}_6\text{O}_4$	Succinic acid.....	0 to 160	$1.039 + 0.00641t$	2	(114, 120)
$\text{C}_4\text{H}_8\text{O}_4$	Dimethyl oxalate.....	10 to 50	$0.887 + 0.0184t$	2	(114)
$\text{C}_4\text{H}_8\text{O}_6$	Tartaric acid.....	36	1.20	2	(137)
$\text{C}_4\text{H}_8\text{O}_6 \cdot \text{H}_2\text{O}$	Tartaric acid.....	-150	0.468	2	(86, 137)
		-100	0.711	1	
		-50	0.966		
		0	1.288	0.5	
		+ 50	1.53	1	
$\text{C}_4\text{H}_7\text{Cl}_2\text{O}_2$	Chloral alcoholate.....	78	2.13	2	(32)
$\text{C}_4\text{H}_{10}\text{O}$	Trimethyl carbinol.....	-4	2.34	2	(92)
$\text{C}_4\text{H}_{10}\text{O}_4$	Erythritol.....	60	1.47	3	(151)
$\text{C}_5\text{H}_8\text{O}_4$	Glutaric acid.....	20	1.25	2	(120)
$\text{C}_5\text{H}_8\text{O}_4$	Pyrotartaric acid.....	20	1.26	2	(120)
$\text{C}_6\text{H}_3\text{N}_3\text{O}_7$	Picric acid.....	-100	0.690	2	(293)
		0	1.004		
		+ 50	1.100		
		100	1.243	3	
		120	1.388		
$\text{C}_6\text{H}_5\text{BrCl}$	<i>o</i> -Bromochlorobenzene.....	-34	0.803	1	(188, 189)
$\text{C}_6\text{H}_5\text{BrCl}$	<i>m</i> -Bromochlorobenzene.....	-52	0.627	1	(188, 189)
$\text{C}_6\text{H}_5\text{BrCl}$	<i>p</i> -Bromochlorobenzene.....	-40	0.629	1	(188, 189)
		0	0.713		
		+ 40	0.756		
		60	0.797		



Formula	Name	<i>t</i> , °C	<i>c<sub>p</sub></i> , joule/g	± %	Lit.
C <sub>6</sub> H <sub>4</sub> BrI	<i>o</i> -Bromiodobenzene.....	-50 to 0	0.5970 + 0.00104 <i>t</i>	1	(188, 189)
C <sub>6</sub> H <sub>4</sub> BrI	<i>m</i> -Bromiodobenzene.....	-75 to -15	0.597	1	(188, 189)
C <sub>6</sub> H <sub>4</sub> BrI	<i>p</i> -Bromiodobenzene.....	-40 to 50	0.4859 + 0.00133 <i>t</i>	1	(188, 189)
C <sub>6</sub> H <sub>4</sub> Br <sub>2</sub>	<i>o</i> -Dibromobenzene.....	-36	1.04	2	(188, 189)
C <sub>6</sub> H <sub>4</sub> Br <sub>2</sub>	<i>m</i> -Dibromobenzene.....	-25	0.56	2	(188, 189)
C <sub>6</sub> H <sub>4</sub> Br <sub>2</sub>	<i>p</i> -Dibromobenzene.....	-50 to 50	0.582 + 0.0016 <i>t</i>	1	(37, 188, 189)
C <sub>6</sub> H <sub>4</sub> Cl <sub>2</sub>	<i>o</i> -Dichlorobenzene.....	-48.5	0.774	2	(188, 189)
C <sub>6</sub> H <sub>4</sub> Cl <sub>2</sub>	<i>m</i> -Dichlorobenzene.....	-52	0.778	2	(188, 189)
C <sub>6</sub> H <sub>4</sub> Cl <sub>2</sub>	<i>p</i> -Dichlorobenzene.....	-50 to 53	0.917 + 0.0086 <i>t</i>	2	(188, 189)
C <sub>6</sub> H <sub>4</sub> I <sub>2</sub>	<i>o</i> -Diiodobenzene.....	-50 to 15	0.456 + 0.0011 <i>t</i>	2	(188, 189)
C <sub>6</sub> H <sub>4</sub> I <sub>2</sub>	<i>m</i> -Diiodobenzene.....	-52 to -42	0.42 + 0.0011 <i>t</i>	2	(188, 189)
C <sub>6</sub> H <sub>4</sub> I <sub>2</sub>	<i>p</i> -Diiodobenzene.....	-50 to 80	0.424 + 0.0012 <i>t</i>	2	(188, 189)
C <sub>6</sub> H <sub>4</sub> N <sub>2</sub> O <sub>4</sub>	<i>o</i> -Dinitrobenzene.....	-160 to M. P.	1.054 + 0.00349 <i>t</i>	3	(3, 4)
C <sub>6</sub> H <sub>4</sub> N <sub>2</sub> O <sub>4</sub>	<i>m</i> -Dinitrobenzene.....	-160 to M. P.	1.038 + 0.00322 <i>t</i>	3	(3, 4)
C <sub>6</sub> H <sub>4</sub> N <sub>2</sub> O <sub>4</sub>	<i>p</i> -Dinitrobenzene.....	119 to M. P.	1.083 + 0.0024 <i>t</i>	2	(4)
C <sub>6</sub> H <sub>4</sub> O <sub>2</sub>	Quinone.....	-250	0.130	3	(34, 141)
		-225	0.343		
		-200	0.473		
		-150 to M. P.	1.182 + 0.00348 <i>t</i>	3	
C <sub>6</sub> H <sub>5</sub> BrO	Bromophenol.....	32	1.10	3	(315)
C <sub>6</sub> H <sub>5</sub> I	Iodobenzene.....	40	0.80	2	(224)
C <sub>6</sub> H <sub>5</sub> NO <sub>2</sub>	Nitrobenzene.....	10	1.50		
		20	1.46		
		40	1.39		
		60	1.38		
		80	1.40		
		100	1.49		
		120	1.65		
C <sub>6</sub> H <sub>6</sub>	Benzene, cf. p. 86.....	-250	0.167	5	(4, 37, 38, 68, 162, 182, 194, 232, 265)
		-225	0.38		
		-200	0.52		
		-150	0.71		
		-100	0.95		
		-50	1.25		
		0	1.57		
C <sub>6</sub> H <sub>5</sub> N <sub>2</sub> O <sub>2</sub>	<i>o</i> -Nitroaniline.....	-160 to M. P.	1.125 + 0.00385 <i>t</i>	3	(3, 4)
C <sub>6</sub> H <sub>5</sub> N <sub>2</sub> O <sub>2</sub>	<i>m</i> -Nitroaniline.....	-160 to M. P.	1.150 + 0.00396 <i>t</i>	3	(3, 4)
C <sub>6</sub> H <sub>5</sub> N <sub>2</sub> O <sub>2</sub>	<i>p</i> -Nitroaniline.....	-160 to M. P.	1.155 + 0.00418 <i>t</i>	3	(3, 4)
C <sub>6</sub> H <sub>4</sub> O <sub>2</sub>	<i>o</i> -Dihydroxybenzene.....	-163 to M. P.	1.165 + 0.00410 <i>t</i>	3	(3, 4)
C <sub>6</sub> H <sub>4</sub> O <sub>2</sub>	<i>m</i> -Dihydroxybenzene.....	-160 to M. P.	1.126 + 0.00495 <i>t</i>	3	(3, 4, 166)
C <sub>6</sub> H <sub>4</sub> O <sub>2</sub>	<i>p</i> -Dihydroxybenzene.....	-250	0.103	10	(3, 4, 141, 166)
		-240	0.160	5	
		-220	0.255	5	
		-200	0.339	5	
		-150 to M. P.	1.120 + 0.00390 <i>t</i>	3	
C <sub>6</sub> H <sub>7</sub> N	Aniline.....	?	3.1	3	(92)
(C <sub>6</sub> H <sub>10</sub> O <sub>5</sub> ) <sub>n</sub>	Dextrin.....	0 to 90	1.22 + 0.0040 <i>t</i>	2	(167, 284)
C <sub>6</sub> H <sub>10</sub> O <sub>5</sub>	Levoglucofuranose.....	40	2.54	3	(211)
C <sub>6</sub> H <sub>12</sub> O <sub>5</sub>	Dextrose.....	-250	0.0648	3	(166, 282)
		-200	0.323	1	
		-100	0.669	0.5	
		0	1.159		
		20	1.257		
C <sub>6</sub> H <sub>12</sub> O <sub>5</sub>	Levulose.....	20	1.15	1	(167)
C <sub>6</sub> H <sub>14</sub> O <sub>6</sub>	Dulcitol.....	20	1.18	2	(166)
C <sub>6</sub> H <sub>14</sub> O <sub>6</sub>	Mannitol.....	0 to 100	1.31 + 0.00106 <i>t</i>	1	(137, 151, 167)
C <sub>7</sub> H <sub>5</sub> ClO <sub>2</sub>	<i>o</i> -Chlorobenzoic acid.....	80 to M. P.	0.953 + 0.00353 <i>t</i>	2	(4)
C <sub>7</sub> H <sub>5</sub> ClO <sub>2</sub>	<i>m</i> -Chlorobenzoic acid.....	94 to M. P.	0.970 + 0.00305 <i>t</i>	2	(4)
C <sub>7</sub> H <sub>5</sub> ClO <sub>2</sub>	<i>p</i> -Chlorobenzoic acid.....	180 to M. P.	1.013 + 0.00232 <i>t</i>	2	(4)
C <sub>7</sub> H <sub>5</sub> NO <sub>4</sub>	<i>o</i> -Nitrobenzoic acid.....	-163 to M. P.	1.073 + 0.00357 <i>t</i>	3	(3, 4)
C <sub>7</sub> H <sub>5</sub> NO <sub>4</sub>	<i>m</i> -Nitrobenzoic acid.....	66 to M. P.	1.079 + 0.00383 <i>t</i>	3	(3, 4)
C <sub>7</sub> H <sub>5</sub> NO <sub>4</sub>	<i>p</i> -Nitrobenzoic acid.....	-160 to M. P.	1.035 + 0.00323 <i>t</i>	3	(3, 4)



Formula	Name	$t$ , °C	$c_p$ , joule/g	$\pm$ %	Lit.
$C_7H_5N_3O_6$	Trinitrotoluene.....	-100	0.71*	5	(75, 238, 293)
		- 50	1.06		
		0	1.30		
		+100	1.61	8	
$C_7H_5N_4O_8$	Tetryl.....	-100	0.761*	1	(238, 293)
		- 50	0.832		
		0	0.887		
		+100	0.987		
$C_7H_6O_2$	Benzoic acid.....	20 to M. P.	1.200 + 0.0021 $\dagger$	2	(4, 120)
$C_7H_7NO_2$	<i>o</i> -Aminobenzoic acid.....	85 to M. P.	1.064 + 0.00570 $\dagger$	5	(4)
$C_7H_7NO_2$	<i>m</i> -Aminobenzoic acid.....	120 to M. P.	1.059 + 0.00512 $\dagger$	5	(4)
$C_7H_7NO_2$	<i>p</i> -Aminobenzoic acid.....	128 to M. P.	1.203 + 0.00368 $\dagger$	5	(4)
$C_7H_6O_2$	Dimethylpyrone.....	50	1.54	2	(237)
$C_7H_9N$	<i>p</i> -Toluidine.....	0	1.41	5	(20)
		20	1.62	2	
		40	1.84	5	
$C_8H_6O_4$	Phthalic acid.....	20	0.97	2	(120)
$C_8H_7N_3O_6$	Trinitroxylylene.....	-185 to 23	1.01 $\dagger$	2	(238)
		20 to 50	1.77 $\dagger$	5	
$C_8H_8O_2$	<i>o</i> -Toluic acid.....	54 to M. P.	1.160 + 0.00504 $\dagger$	3	(4)
$C_8H_8O_2$	<i>m</i> -Toluic acid.....	54 to M. P.	0.999 + 0.00818 $\dagger$	3	(4)
$C_8H_8O_2$	<i>p</i> -Toluic acid.....	130 to M. P.	1.133 + 0.00443 $\dagger$	3	(4)
$C_8H_9NO_2$	Hydroxyacetanilide.....	41 to M. P.	1.043 + 0.00646 $\dagger$		(4)
$C_8H_{10}O_2$	Caprylic acid.....	- 2	2.63	3	(105)
$C_{10}H_7Br$	$\beta$ -Bromonaphthalene.....	41	1.09	2	(224)
$C_{10}H_7NO_2$	Nitronaphthalene.....	0 to 55	0.989 + 0.0090 $\dagger$	2	(21, 55)
$C_{10}H_8$	Naphthalene.....	-130 to M. P.	1.176 + 0.00464 $\dagger$	5	(4, 20, 37, 67, 293)
$C_{10}H_8O$	$\alpha$ -Naphthol.....	50 to M. P.	1.004 + 0.00615 $\dagger$	2	(4)
$C_{10}H_8O$	$\beta$ -Naphthol.....	61 to M. P.	1.056 + 0.00534 $\dagger$	2	(4)
$C_{10}H_9N$	$\alpha$ -Naphthylamine.....	0 to 50	1.13 + 0.013 $\dagger$	2	(21, 55)
$C_{10}H_{14}O$	Thymol.....	0 to 49	1.32 + 0.013 $\dagger$	3	(19, 51)
$C_{10}H_{16}$	Camphene.....	35	1.59	2	(258)
$C_{10}H_{20}O_2$	Capric acid.....	8	2.91	3	(105)
$C_{12}H_{10}$	Diphenyl.....	40	1.61	2	(87)
$C_{12}H_{10}N_2$	Azobenzene.....	28	1.38	1	(38, 87)
$C_{12}H_{10}O_4$	Quinhydrone.....	-250	0.0690	1	(141)
		-225	0.2558		
		-200	0.410		
		-100	0.799		
		0	1.071		
$C_{12}H_{11}N$	Diphenylamine.....	26	1.41	2	(20, 55)
$C_{12}H_{14}O_4$	Apiol.....	10	1.25	3	(291)
$C_{12}H_{22}O_{11}$	Lactose.....	20	1.20	1	(167)
$C_{12}H_{22}O_{11} \cdot H_2O$	Lactose.....	20	1.25	1	(167)
$C_{12}H_{22}O_{11}$	Maltose.....	20	1.34	1	(167)
$C_{12}H_{22}O_{11}$	Sucrose.....	20	1.25	1	(167)
$C_{12}H_{24}O_2$	Lauric acid.....	-30 to 40	1.80 + 0.000114 $\dagger$	1	(105, 177)
$C_{12}H_5N_3O_{15}$	1 Tetryl + 1 Picric acid.....	-100 to 100	1.06 + 0.0030 $\dagger$	2	(293)
$C_{12}H_{10}O$	Benzophenone.....	-150	0.48	5	(198, 291)
		-100	0.72	3	
		- 50	0.92	1	
		0	1.15		
		+ 20	1.27		
$C_{12}H_{10}O_2$	Salol.....	32	1.21	1	(55)
$C_{14}H_8O_2$	Anthraquinone.....	0 to 270	1.079 + 0.0029 $\dagger$	1	(121)
$C_{14}H_{10}$	Anthracene.....	50	1.288	0.5	(121)
		100	1.464		
		150	1.597		
$C_{14}H_{14}$	Dibenzyl.....	28	1.52	1	(38)
$C_{14}H_{20}O_2$	Myristic acid.....	0 to 35	1.593 + 0.0228 $\dagger$	2	(105, 268, 285)
$C_{16}H_{32}O_2$	Palmitic acid.....	-180	0.70	2	(105, 219)
		-140	0.87		
		-100	1.05		

\* There is serious discrepancy between the authors.  $\dagger$  Mean over the range.



Formula	Name	$t$ , °C	$c_p$ , joule/g	± %	Lit.
$\text{C}_{16}\text{H}_{32}\text{O}_2$	Palmitic acid.—(Cont'd).....	— 50	1.28		
		0	1.60		
$\text{C}_{16}\text{H}_{34}$	Hexadecane.....	+ 20	1.80		
$\text{C}_{17}\text{H}_{34}\text{O}_2$	Betol.....	19	2.07	2	(16)
		—150	0.54	2	(193, 195)
		—100	0.70		
		0	1.04		
$\text{C}_{18}\text{H}_{36}\text{O}_2$	Stearic acid.....	+ 50	1.29		
$\text{C}_{19}\text{H}_{40}$	Triphenylmethane.....	15	1.67	4	(105)
$\text{C}_{21}\text{H}_{16}\text{N}_{11}\text{O}_8$	1 Tetryl + 2 TNT.....	0 to 91	0.791 + 0.0114t	0.5	(121)
		—100	0.72	5	(293)
		0	1.17		
		+ 50	1.36		
$\text{C}_{27}\text{H}_{54}\text{O}_2$	Cerotic acid.....	15	1.62	3	(105)

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## THERMAL PROPERTIES OF SILICA

ROBERT B. SOSMAN

HEAT CAPACITY (2, 3, 4, 8, 9, 10, 11, 12, 14, 16, 17, 18, 19, 20, 21, 23, 24, 25, 26)

VALUES OF $c_p$ AT $t$ , °C, JOULE/G				VALUES OF $c_m$ BETWEEN 0 AND $t$ , °C, JOULE/G			
$t$ , °C	Quartz	Cristobalite*	Vitreous	$t$ , °C	Quartz	Cristobalite*	Vitreous
—255			0.0200	—250	0.382	0.399	0.391
—250	0.0226	0.0284	0.0322	—200	.454	.470	.460
—243	.0398	.0468	0.0531	—150	.523	.539	.527
—233	.0669	.0761	0.0828	—100	.588	.602	.590
—223	.0988	.106	0.112	— 50	.645	.661	.646
—200	.171	.184	0.181	0	.696	.711	.693
—150	.324	.339	0.332	+ 50	.740	.750	.736
—100	.465	.481	0.472	100	.779	.795	.773
— 50	.590	.606	0.594	150	.815	.836	.807
0	.696	.717	0.693	200	.847	.888	.836
+ 50	.782	.790	0.773	225		.916†	
100	.854	.882	0.840			.937†	
150	.917	.978	0.899	250	.878	.949	.861
200	.973	1.095	0.947	300	.905	.966	.886
250	1.022	1.033	0.988	350	.930	.978	.907
300	1.063	1.049	1.027	400	.953	.991	.928
350	1.098	1.070	1.060	450	.974	1.003	.949
400	1.129	1.091	1.088	500	.995	1.016	.966
450	1.162	1.112	1.112	550	1.019	1.029	.983
500	1.217	1.133	1.131	573	1.033†		
550	1.321	1.150	1.141		1.052†		
573	1.422(?)			600	1.055	1.037	.995
600	1.133	1.162	1.150	700	1.067	1.058	1.020
700	1.146	1.187	1.175	800	1.077	1.075	1.041
800	1.157	1.208	1.196	900	1.085	1.091	1.058
900	1.168	1.221	1.208	1000	1.094	1.104	1.075
1000	1.178	1.225	1.221	1100	1.103	1.116	1.087
1100	1.187	1.230	1.229	1200	1.110	1.125	1.100
1200	1.194	1.237	1.267	1300	1.117	1.133	1.116
1300	1.202	1.25	1.321	1400	1.125	1.141	1.129
1400	1.212	1.26	1.371	1500		1.150	1.150
1500		1.27	1.417	1600		1.158	1.166
1600		1.27	1.447	1700		1.166	1.183
1700		1.27	1.472				

\* Made at 1100°C.

\* Made at 1100°C. † Low modification. ‡ High modification.



## LATENT HEATS OF TRANSFORMATION (3, 13, 15, 16, 24, 25)

Transformation	$t$ , °C	Heat absorbed at $t^\circ$ , joule/g
High-cristobalite $\rightarrow$ liquid (fusion)....	1710	71
High-quartz $\rightarrow$ liquid (fusion).....	1710*	210
Low-quartz $\rightarrow$ high-quartz.....	573	10.5
Low-1100°-cristobalite $\rightarrow$ high-1100° cristobalite†.....	230	4.2
Low-1600°-cristobalite $\rightarrow$ high-1600°- cristobalite†.....	270	10.5

\* This temperature is not the melting point of quartz; it is selected merely for the sake of the comparison with cristobalite. The difference in heat content between quartz and liquid or vitreous silica at any other temperature can be calculated from this with the aid of the heat capacities.

† Cristobalites made at different temperatures differ in inversion point and in various other ways.

## LITERATURE

(For a key to the periodicals see end of volume)

- (1) Barratt, 67, 27: 81; 15. (2) Bornemann and Hengstenberg, 187, 17: 313; 20. (3) Cohn, 38, 7: 359, 475, 548; 24. (4) Dieterici, 8, 16: 593; 05. (5) Eucken, 8, 34: 185; 11. (6) Eucken, 88, 13: 829; 11. (7) Griffiths and Kaye, 5, 104: 71; 23. (8) Heinrichs, Diss., Bonn, 1906. (9) Hildebrand, Duscha, Foster and Beebe, 1, 39: 2293; 17. (10) Joly, 5, 41: 250; 87. (11) Koref, 8, 36: 49; 11. (12) Magnus, 63, 14: 5; 13.

## THERMAL CONDUCTIVITY (1, 5, 6, 7, 22)

Values of  $10^3k$ ; unit of  $k$ , joule  $\text{cm}^{-2} \text{sec}^{-1} (\text{°C cm}^{-1})^{-1}$

$t$ , °C	Quartz    to axis	Quartz $\perp$ to axis	Vitreous
-252		2848	
-250		2135	ca. 5.4
-240		858	
-200	ca. 630	276	6.3
-150	310	151	8.4
-100	218	109	10.5
-50	167	86	12.5
0	134	71	14.2
+50	107	62	15.9
100	88	55	ca. 19

- (13) Mulert, 93, 75: 198; 12. (14) Nernst, 8, 36: 395; 11. (15) Neumann 190B, 53A: 1; 26. 93, 145: 193; 25. (16) Perrier and Roux, Mém. Soc. Sci. Nat. Vaudoise, 1: 109; 23. (17) Pionchon, 34, 106: 1344; 88. (18) Schulz, 189, 1912: 481. (19) Simon, 8, 68: 241; 22. (20) Sosman, Properties of Silica. New York, Chem. Cat. Co., 1927. (21) Stierlin, 242, 52: 382; 07. (22) Tuschmidt, Diss., Zürich, 1883. (23) White, 12, 28: 334; 09. (24) White, 12, 47: 1; 19. (25) Wietzel, 93, 116: 71; 21. (26) Wietzel and Günther, 93, 116: 88; 21.

## THE HEAT CAPACITY OF CHEMICAL COMPOUNDS IN THE LIQUID STATE

HOWARD T. BARNES

A value in the  $c_p$  column represents the heat capacity in joules per gram per deg C under atmospheric pressure and at  $t^\circ$  (or the mean  $c_p$  over  $\Delta t^\circ$ ); unless the value is enclosed in parentheses, in which case it represents merely the parameter  $c_0$  in the equation

$$c_p = c_0 + at + bt^2 + \dots$$

which equation is valid over the range given.

Une valeur mentionnée dans la colonne des  $c_p$ , représente la capacité calorifique en joules par gramme et par degré C, sous la pression atmosphérique et à  $t^\circ$  (ou la valeur moyenne  $c_p$  pour  $\Delta t^\circ$ ), à moins que la valeur ne soit comprise entre parenthèses, auquel cas elle représente seulement le paramètre  $c_0$  de l'équation

$$c_p = c_0 + at + bt^2 + \dots$$

cette équation étant valable pour l'intervalle donné.

Ein in der  $c_p$ -Kolonne stehender Wert bedeutet den Wärmehalt in Joule pro Gramm pro Grad C, unter dem Druck 1 Atmosphäre bei  $t^\circ$  (oder das Mittel  $c_p$  im  $\Delta t^\circ$  Intervall). In Klammer gesetzte Werte bedeuten, dass nur etwa der Parameter  $c_0$  der Gleichung  $c_p = c_0 + at + bt^2 + \dots$  vorliegt. Diese gilt innerhalb des angegebenen Temperaturbereiches.

I valori della colonna  $c_p$  rappresentano la capacità termica in joules, per ogni grammo e grado centigrado alla pressione atmosferica e a  $t^\circ$  (oppure il  $c_p$  medio nell'intervallo  $\Delta t^\circ$ ). I valori racchiusi tra parentesi rappresentano soltanto il termine  $c_0$  della equazione

$$c_p = c_0 + at + bt^2 + \dots$$

la quale è valida entro i limiti dati.

## B-TABLE

Substance	$t$ or $\Delta t$ , °C	$c_p$ , joule/g	$\pm$ %	Lit.	Substance	$t$ or $\Delta t$ , °C	$c_p$ , joule/g	$\pm$ %	Lit.
H <sub>2</sub> O.....	v. p. 113				PbBr <sub>2</sub> .....	550	0.326	1	(98)
H <sub>2</sub> O <sub>2</sub> .....	0-18	2.42	2	(161)	TlCl.....	480	0.247	1	(97)
HCl, HBr, HI.....	v. p. 86				TlBr.....	500	0.335	1	(97)
ICl.....	15-77	0.661	1	(286)	AgCl.....	490	0.540	1	(97)
SO <sub>2</sub> .....	v. p. 114				AgBr.....	500	0.318	1	(98)
H <sub>2</sub> SO <sub>4</sub> .....	v. p. 114				AgNO <sub>3</sub> .....	250	0.783	1	(109)
H <sub>2</sub> S <sub>2</sub> O <sub>7</sub> .....	35	1.4	10	(6)		>218	0.816	1	(98)
S <sub>2</sub> Cl <sub>2</sub> .....	12-70	0.921	1	(207)	Mg <sub>2</sub> Si <sub>2</sub> O <sub>7</sub> .....	v. Vol. II, p. 101			
SOCl <sub>2</sub> .....	17-60	1.013	1	(208)	CaCl <sub>2</sub> ·6H <sub>2</sub> O.....	33-99	2.310	1	(228)
SO <sub>2</sub> Cl <sub>2</sub> .....	15-63	0.975	1	(208)	Ca <sub>2</sub> Si <sub>2</sub> O <sub>7</sub> .....	v. Vol. II, p. 101			
NO.....	v. p. 86				LiNO <sub>3</sub> .....	280	1.632	1	(98)
NH <sub>3</sub> .....	v. p. 86, 114				NaClO <sub>3</sub> .....	280	1.360	1	(98)
CO.....	v. p. 86				Na <sub>2</sub> S <sub>2</sub> O <sub>5</sub> ·5H <sub>2</sub> O.....	13-98	2.385	1	(303)
CO <sub>2</sub> .....	v. p. 114				NaNO <sub>3</sub> .....	350	1.800	1	(98)
SiO <sub>2</sub> .....	v. p. 105				NaC <sub>2</sub> H <sub>3</sub> O <sub>2</sub> .....	61.8	3.541	0.5	(96)
SiCl <sub>4</sub> .....	12-50	0.837	1	(205)	Na <sub>2</sub> Si <sub>2</sub> Al <sub>2</sub> O <sub>7</sub> .....	v. Vol. II, p. 101			
(CH <sub>3</sub> ) <sub>2</sub> SiO <sub>4</sub> .....	23-115	2.097	0.5	(134)	KNO <sub>3</sub> .....	380	0.139	5	(98)
TiCl <sub>4</sub> .....	13-99	0.804	1	(240)	K <sub>2</sub> Si <sub>2</sub> Al <sub>2</sub> O <sub>7</sub> .....	v. Vol. II, p. 101			
SaCl <sub>4</sub> .....	14-98	0.619	1	(240)	K <sub>2</sub> Cr <sub>2</sub> O <sub>7</sub> .....	>397	0.140	1	(98)
PbCl <sub>4</sub> .....	540	0.506	1	(98)					



C-TABLE, C-ARRANGEMENT (v. Vol. III, p. viii)

$$c_p = c_0 + at + bt^2$$

Formula	Name	<i>t</i> or $\Delta t$ , °C	<i>c<sub>p</sub></i> , joule/g	± %	10 <sup>3</sup> <i>a</i>	Range, °C	Lit.
CCl <sub>4</sub>	Carbon tetrachloride.....	0	0.827	0.5	0.8	20-60	(247)
		20	0.841	1	0.13	0-70	(182)
		20	0.833	0.5			(319)
		30	0.837	0.2	1.97	20-60	(321)
CS <sub>2</sub>	Carbon disulfide.....	v. p. 114					
CHCl <sub>3</sub>	Chloroform.....	0	0.971	0.5	0.322*	20-40	(247)
		15	0.946	0.5	1.38	-30 to 60	(302)
		20	0.978	0.5			(275)
		20	0.968	0.5			(319)
CH <sub>2</sub> Cl <sub>2</sub>	Methylene chloride.....	30	0.979	0.2	1.27	20-60	(321)
		15-40	1.205	0.5			(31)
		0	2.078	0.5	2.97	40-140	(266)
CH <sub>3</sub> O <sub>2</sub>	Formic acid.....	0	1.83	1			(250)
		15.5	2.139	0.4			(94)
		20-100	2.201	1			(250)
CH <sub>3</sub> NO	Formamide.....	19	2.306	0.5			(310)
CH <sub>3</sub> NO <sub>2</sub>	Nitromethane.....	17	1.724	0.5			(310)
		(CaCl <sub>2</sub> -dried).....	0	(1.664)	-1.42†	30-70	(320)
		(P <sub>2</sub> O <sub>5</sub> -dried).....	0	(1.76)	-3.19‡	15-70	(320)
CH <sub>4</sub>	Methane.....	v. p. 86					
CH <sub>3</sub> O	Methyl alcohol.....	v. p. 114					
C <sub>2</sub> Cl <sub>4</sub>	Tetrachloroethylene.....	20	0.883	1			(250)
		20	0.904	0.4			(118)
C <sub>2</sub> HCl <sub>3</sub>	Trichloroethylene.....	20	0.933	0.4			(118)
C <sub>2</sub> HCl <sub>3</sub> O	Chloral.....	17-53	1.046	0.5			(27)
C <sub>2</sub> H <sub>2</sub> Cl <sub>2</sub> O <sub>2</sub>	Dichloroacetic acid.....	21-106	1.465	0.5			(156)
		21-196	1.464	0.5			(155)
C <sub>2</sub> H <sub>2</sub> Cl <sub>4</sub>	Tetrachloroethane.....	20	1.122	0.4			(118)
C <sub>2</sub> H <sub>2</sub> ClO	Acetyl chloride.....	0	1.419	1.0			(250)
C <sub>2</sub> H <sub>2</sub> Cl <sub>3</sub>	Trichloroethane.....	20	1.113	0.5			(118)
C <sub>2</sub> H <sub>2</sub> Cl <sub>3</sub> O <sub>2</sub>	Chloral hydrate.....	55-88	1.967	0.5			(27)
C <sub>2</sub> H <sub>3</sub> N	Acetonitrile.....	21-76	2.264	0.5			(153)
		8-95	0.766	1.0			(30)
		13-106	0.734	0.5			(247)
		20	0.728	0.5			(247)
C <sub>2</sub> H <sub>4</sub> Cl <sub>2</sub>	Ethylene chloride.....	-30	1.168	0.5			(247)
		+20	1.258	0.5			(275)
		30	1.276	0.5			(247)
		50	1.316	0.5			(275)
		60	1.335	0.5			(247)
C <sub>2</sub> H <sub>4</sub> O <sub>2</sub>	Acetic acid.....	v. p. 114					
C <sub>2</sub> H <sub>5</sub> O <sub>2</sub>	Methyl formate.....	13-29	2.159	0.5			(33)
		-100	0.816	1.0			(21)
		-20	0.866	1.0			(21)
C <sub>2</sub> H <sub>5</sub> Br	Ethyl bromide.....	5-10	0.906	0.5			(251)
		10-15	0.894	0.5			(241)
		15-20	0.901	0.5			(241)
		-28 to +4	1.790	0.5			(247)
C <sub>2</sub> H <sub>5</sub> Cl	Ethyl chloride.....	0	1.542	0.5	2.43	-30 to 40	(131)
		-30	0.656	0.5			(247)
		60	0.718	0.5			(247)
C <sub>2</sub> H <sub>5</sub> I	Ethyl iodide.....	0	0.676	0.5	6.91	-30 to 60	(247)
		v. p. 114					
		0	2.277	0.5	5.0	-20 to 200	(91, 152, 276)
C <sub>2</sub> H <sub>5</sub> O	Glycol.....	-11.1	2.247	1			(219)
		+2.5	2.310	1			(219)
		5.1	2.327	1			(219)
		14.9	2.390	1			(219)
C <sub>2</sub> H <sub>5</sub> Cl <sub>3</sub> O <sub>2</sub>	Methyl trichloroacetate.....	19.9	2.406	1			(219)
		20	1.117	0.5	1.69	10-140	(266)
		20	1.302	0.5	1.6	10-140	(266)
C <sub>2</sub> H <sub>5</sub> Cl	Allyl chloride.....	0	1.310	1			(250)

\* 10% = 1.55. † 10% = 34.2. ‡ 10% = 25.2.



Formula	Name	$t$ or $\Delta t$ , °C	$c_p$ , joule/g	$\pm$ %	$10^3 \alpha$	Range, °C	Lit.
$C_3H_5ClO_2$	Methyl chloroacetate.....	20	1.600	0.5	1.6	10-160	(266)
$C_3H_5N$	Propionitrile.....	0	2.128	0.5			(247)
		19-95	2.252	0.5			(155)
$C_3H_5O$	Allyl alcohol.....	0	1.615	1.0			(250)
		21-96	2.785	0.5			(152)
$C_3H_5O$	Propionaldehyde.....	0	2.185	1			(250)
		3-22.6	2.151	0.5			(158)
		0	(2.118)	0.5	3.2	-30 to +60	(247)
$C_3H_5O$	Acetone.....	24.2-49.4	2.251	1			(158)
		20	2.210				(301)
		20	2.166	0.5			(319)
		0	2.134	0.5	3.35	22-50	(302)
$C_3H_5O_2$	Propionic acid.....	0	1.858	0.5	0.593	10-140	(265)
		20-137	2.342	0.5			(155)
$C_3H_5O_2$	Ethyl formate.....	14-49	2.136	0.5			(33)
		-20 to +14	1.909	0.5			(187)
$C_3H_5O_2$	Methyl acetate.....	15	1.96				(269)
$C_3H_5O_2$	Dimethyl carbonate.....	19.8-88	1.892	0.5			(155)
$C_3H_8$	Propane.....	0	2.41	2	6.3	-30 to 20	(63)
$C_3H_5O$	Propyl alcohol.....	v. p. 114					
$C_3H_5O_2$	Methylal.....	15-41	2.180	1			(21)
$C_3H_5O_2$	Glycerol.....	v. p. 114					
		10-81	1.235	0.5			(266)
$C_4H_5Cl_3O_2$	Ethyl trichloroacetate.....	9-139	1.280	0.5			(266)
		20	1.193	0.5	1.6	10-140	(266)
$C_4H_5Cl_2O_2$	Ethyl dichloroacetate.....	20	1.377	0.5			(266)
$C_4H_5O_2$	Crotonic acid.....	71.4	2.093	1.0	6.37		(159)
$C_4H_7ClO_2$	Ethyl chloroacetate.....	9-138	1.749	0.5			(266)
		20	1.666	0.5	1.6	10-140	(266)
$C_4H_7N$	<i>n</i> -Butyronitrile.....	21-113	2.290	0.5			(155)
$C_4H_5O$	Methyl ethyl ketone.....	20-78	2.299	0.5			(152)
		0	1.858	0.5			(265)
$C_4H_5O_2$	<i>n</i> -Butyric acid.....	40	2.097	0.5			(265)
		20-100	2.155	0.5			(250)
$C_4H_5O_2$	Isobutyric acid.....	20	1.883	1			(250)
$C_4H_5O_2$	Ethyl acetate.....	20	1.921	0.5			(265)
		20	2.000	0.5			(300)
$C_4H_5O_2$	Methyl propionate.....	20	1.921	0.5			(265)
$C_4H_5O_2$	<i>n</i> -Propyl formate.....	20	1.921	0.5			(265)
$C_4H_9Cl$	<i>n</i> -Butyl chloride.....	20	1.887	0.5			(301)
$C_4H_9NO$	Methyl ethyl ketoxime.....	21.8-151.5	2.722	0.5			(155)
$C_4H_{10}$	<i>n</i> -Butane.....	0	2.30	2	8.0	-15 to 20	(63)
	Isobutane.....	0	2.30	2	19		
		21-115	2.876	0.5			(250)
		21-115	2.883	0.5			(152)
		30	2.436	0.2	11.01*	30-80	(321)
$C_4H_{10}O$	<i>n</i> -Butyl alcohol.....	-76.2	1.854	0.5			(218)
		-33.3	1.896	0.5			(218)
		2.3	2.201	0.5			(218)
		19.2	2.356	0.5			(218)
$C_4H_{10}O$	Isobutyl alcohol.....	21-109	2.996	0.5			(152)
		30	2.525		13.68†	20-80	(321)
		-100	2.147	1			(21)
		-50	2.164	1			(21)
		-5	2.205	0.5			(187)
		0	2.189	1			(21)
$C_4H_{10}O$	Ether.....	0	2.214	0.5			(247)
		+30	2.289	0.5			(247)
		80	2.888	0.5			(289)
		120	3.361	0.5			(289)
		140	3.440	0.5			(115)
		180	4.357	0.5			(115)

\*  $10^3 \alpha = 7.5$ . †  $10^3 \alpha = 10.5$ .



Formula	Name	<i>t</i> or $\Delta t$ , °C	<i>c<sub>p</sub></i> , joule/g	± %	10 <sup>a</sup>	Range, °C	Lit.
C <sub>2</sub> H <sub>6</sub> S	Ethyl sulfide.....	0	(1.967)	0.5	0.75	5-70	(241)
		5-10	1.973	0.5			(241)
		10-15	1.989	0.5			(241)
		15-20	1.997	0.5			(241)
		20-70	2.003	0.5			(241)
C <sub>2</sub> H <sub>11</sub> N	Diethylamine.....	22.5	2.168	0.5			(187)
C <sub>2</sub> H <sub>4</sub> O <sub>2</sub>	Furfural.....	0	1.54 <sub>0</sub>	1			(250)
		20-100	1.74 <sub>9</sub>	1			(250)
C <sub>2</sub> H <sub>5</sub> Cl <sub>3</sub> O <sub>2</sub>	Allyl trichloroacetate.....	20	1.205	0.5			(266)
C <sub>2</sub> H <sub>5</sub> N	Pyridine.....	20	1.695	0.5	1.6	20-110	(301)
		21-108	1.804	0.5			(153)
		0-20	1.653	0.5			(45)
C <sub>2</sub> H <sub>5</sub> Cl <sub>2</sub> O <sub>2</sub>	Allyl dichloroacetate.....	20	1.389	0.5	1.6	10-140	
C <sub>2</sub> H <sub>7</sub> ClO <sub>2</sub>	Allyl chloroacetate.....	20	1.657	0.5			1.6
C <sub>2</sub> H <sub>7</sub> Cl <sub>2</sub> O <sub>2</sub>	Propyl trichloroacetate.....	20	1.243	0.5			1.6
C <sub>2</sub> H <sub>5</sub> Cl <sub>2</sub> O <sub>2</sub>	Propyl dichloroacetate.....	20	1.427	0.5	1.6		
C <sub>2</sub> H <sub>5</sub> O <sub>2</sub>	Allyl acetate.....	0	1.802	0.5	3.68		
C <sub>2</sub> H <sub>5</sub> ClO <sub>2</sub>	Propyl chloroacetate.....	20	1.733	0.5	1.6		
C <sub>2</sub> H <sub>5</sub> N	Valeronitrile.....	23-121	2.176	0.5			(133)
C <sub>2</sub> H <sub>10</sub>	Amylene.....	0	1.18 <sub>0</sub>	1.0			(250)
C <sub>2</sub> H <sub>10</sub> O	Diethyl ketone.....	20-98.5	2.332	0.5			(152)
C <sub>2</sub> H <sub>10</sub> O	Methyl isopropyl ketone.....	20-91	2.198	0.5			(152)
C <sub>2</sub> H <sub>10</sub> O <sub>2</sub>	Isovaleric acid.....	20	1.938	0.5	5.93	10-140	(266)
		23-93	2.469	0.5			(105)
C <sub>2</sub> H <sub>10</sub> O <sub>2</sub>	<i>n</i> -Butyl formate.....	20	1.921	0.5			(265)
C <sub>2</sub> H <sub>10</sub> O <sub>2</sub>	Ethyl propionate.....	20	1.921	0.5			(266)
C <sub>2</sub> H <sub>10</sub> O <sub>2</sub>	Methyl <i>n</i> -butyrate.....	20	1.921	0.5			(265)
C <sub>2</sub> H <sub>10</sub> O <sub>2</sub>	<i>n</i> -Propyl acetate.....	20	1.921	0.5			(265)
C <sub>2</sub> H <sub>10</sub> O <sub>3</sub>	Diethyl carbonate.....	0	1.03 <sub>0</sub>	1.0			(250)
		20-100	1.94 <sub>2</sub>	1.0			(250)
		20.2-123	1.986	0.5			(152)
C <sub>2</sub> H <sub>11</sub> N	Piperidine.....	20-98	2.189	0.5			(153)
C <sub>2</sub> H <sub>12</sub>	Isopentane.....	0	2.145	0.5			(268)
		8	2.204	0.5			(308)
		40	1.93 <sub>8</sub>	1.0			(21)
		0	(2.101)	0.5			(265)
C <sub>2</sub> H <sub>12</sub> O	Isoamyl alcohol.....	20	2.239	0.5	10.21*	0-130	(265)
		10-117	2.900	0.5			(247)
		21-130	2.911	0.5			(152)
		75.5	2.87 <sub>8</sub>	1.0			(250)
		30	2.385	0.2	10.67†	30-80	(321)
		47.9	2.77			(158)	
C <sub>2</sub> H <sub>12</sub> O	<i>tert.</i> -Amyl alcohol.....	20-99	3.15	0.5			(152)
C <sub>2</sub> H <sub>12</sub> O	<i>d</i> -prim.-Amyl alcohol.....	22-125	2.978	0.5			(152)
C <sub>2</sub> H <sub>12</sub> N	Isoamylamine.....	22-91	2.570	0.5			(134)
C <sub>2</sub> H <sub>4</sub> BrCl	<i>o</i> -Bromochlorobenzene.....	0	0.899	0.5	0.98	0-100	
C <sub>2</sub> H <sub>4</sub> BrCl	<i>m</i> -Bromochlorobenzene.....	0	0.888	0.5	0.98		(188)
		0	(0.639)	0.5	0.557		
C <sub>2</sub> H <sub>4</sub> BrI	<i>o</i> -Bromiodobenzene.....	5-100	0.668	0.5			(188)
		3.2-64.6	0.658	0.5			(188)
		1.8-34	0.657	0.5			(188)
C <sub>2</sub> H <sub>4</sub> BrI	<i>m</i> -Bromiodobenzene.....	0	(0.635)	0.5	0.557‡	0-100	(188)
		5-100	0.663	0.5			(188)
		3.2-64.5	0.652	0.5			(188)
		1.7-34.1	0.644	0.5			(188)
		1.7-36.2	0.624	0.5			(188)
C <sub>2</sub> H <sub>4</sub> Br <sub>2</sub>	<i>o</i> -Dibromobenzene.....	0	0.753	0.5	0.89 <sub>6</sub>	0-100	(188)
C <sub>2</sub> H <sub>4</sub> Br <sub>2</sub>	<i>m</i> -Dibromobenzene.....	0	0.734	0.5	0.89 <sub>6</sub>		(188)
C <sub>2</sub> H <sub>4</sub> Cl <sub>2</sub>	<i>o</i> -Dichlorobenzene.....	0	1.131	0.5	1.27		(188)
C <sub>2</sub> H <sub>4</sub> Cl <sub>2</sub>	<i>m</i> -Dichlorobenzene.....	0	1.131	0.5	1.27		
C <sub>2</sub> H <sub>4</sub> Cl <sub>2</sub>	<i>p</i> -Dichlorobenzene.....	53-99	1.247	0.5			(188)
C <sub>2</sub> H <sub>4</sub> I <sub>2</sub>	<i>o</i> -Diiodobenzene.....	0	0.568	0.5	0.325	0-100	(188)
C <sub>2</sub> H <sub>4</sub> I <sub>2</sub>	<i>m</i> -Diiodobenzene.....	34.2-99.6	0.586	0.5			(188)
C <sub>2</sub> H <sub>4</sub> N <sub>2</sub> O <sub>4</sub>	<i>o</i> -Dinitrobenzene.....	0	(1.46 <sub>2</sub> )	1	1.39	M. P. to 357	(4)
C <sub>2</sub> H <sub>4</sub> N <sub>2</sub> O <sub>4</sub>	<i>m</i> -Dinitrobenzene.....	M. P.	1.697	1	0.0	M. P. to 235	(4)

\* 10<sup>b</sup> = 17. † 10<sup>b</sup> = 3.8<sub>8</sub>. ‡ 10<sup>b</sup> = 1.2

\* 10<sup>b</sup> = 17. † 10<sup>b</sup> = 3.85. ‡ 10<sup>b</sup> = 1.3.



Formula	Name	$t$ or $\Delta t$ , °C	$c_p$ , joule/g	$\pm$ %	$10^3 \alpha$	Range, °C	Lit.
$C_6H_4N_2O_4$	<i>p</i> -Dinitrobenzene	0	(1.169)	1	2.76	M. P. to 384	(4)
$C_6H_4O_2$	Quinone	0	(1.355)	1	3.41	M. P. to 273	(4)
		0	0.900	1			(250)
$C_6H_5Br$	Bromobenzene	20	0.965	0.5			(319)
		20-100	1.030	1			(250)
$C_6H_5BrO$	Bromophenol	16.9-65	1.000	0.5			(139)
		18-77	1.322	1.0			(315)
$C_6H_5Cl$	Chlorobenzene	0	1.147	1.0			(250)
		0	1.250	0.5	3.10	10-140	(266)
$C_6H_5ClO$	<i>o</i> -Chlorophenol	20	1.294	0.5			(319)
		0-20	1.678	0.5			(45)
		10	1.499	0.5			(275)
		30	1.420	0.5			(275)
$C_6H_5NO_2$	Nitrobenzene	50	1.380	0.5			(275)
		70	1.381	0.5			(275)
		90	1.435	0.5			(275)
		120	1.648	0.5			(275)
$C_6H_6$	Benzene	v. p. 115					
$C_6H_5Cl_2O_2$	Ethylene dichloroacetate	0	1.348	0.5	1.6	10-140	(266)
$C_6H_5N_2O_2$	<i>o</i> -Nitroaniline	0	(1.675)	1	2.65	M. P. to 219	(4)
$C_6H_5N_2O_2$	<i>m</i> -Nitroaniline	0	(1.641)	1	2.42	M. P. to 322	(4)
$C_6H_5N_2O_2$	<i>p</i> -Nitroaniline	0	(1.787)	1	1.45	M. P. to 343	(4)
$C_6H_5O$	Phenol	14-26	2.348	0.5			(166)
$C_6H_5O_2$	<i>o</i> -Dihydroxybenzene	0	(1.935)	1	2.28	M. P. to 304	(4)
$C_6H_5O_2$	<i>m</i> -Dihydroxybenzene	0	(1.891)	1	2.66	M. P. to 310	(4)
$C_6H_5O_2$	<i>p</i> -Dihydroxybenzene	0	(2.060)	1	1.67	M. P. to 372	(4)
$C_6H_7N$	$\alpha$ -Picoline	22-124	1.816	0.5			(133)
$C_6H_7N$	Aniline	v. p. 115					
$C_6H_{10}$	1, 5-Hexadiene	0	1.703	1.0			(250)
$C_6H_{10}O$	Cyclohexanone	15-18	1.812	0.5			(119)
$C_6H_{10}O$	Mesityl oxide	21-121	2.182	0.5			(152)
$C_6H_{10}O_2$	Allyl propionate	20	1.887	0.5	3.68	10-140	(266)
		0	1.800	1			(250)
$C_6H_{10}O_2$	Ethyl acetoacetate	20-100	1.996	1			(250)
$C_6H_{10}O_4$	Diethyl oxalate	20	1.812	0.5	2.76	10-140	(266)
$C_6H_{11}N$	Capronitrile	18-156	2.268	1.0			(153)
$C_6H_{12}$	Hexylene	0-50	2.118	0.4			(163)
$C_6H_{12}O$	Cyclohexanol	15-18	1.745	0.5			(119)
$C_6H_{12}O$	Methyl butyl ketone	21-127	2.313	0.5			(155)
$C_6H_{12}O$	Methyl isobutyl ketone	20	1.921	0.5			(265)
$C_6H_{12}O_2$	Caproic acid	29-105	2.231	0.5			(105)
$C_6H_{12}O_2$	Isoamyl formate	16-65	2.130	0.5			(139)
		20	1.921	0.5			(265)
$C_6H_{12}O_2$	Isobutyl acetate	20	1.921	0.5	2.76	0-110	(265)
$C_6H_{12}O_2$	Ethyl butyrate	20	1.921	0.5			(266)
$C_6H_{12}O_2$	Ethyl isobutyrate	20	1.921	0.5			(266)
$C_6H_{12}O_2$	Methyl valerate	20	1.921	0.5			(265)
$C_6H_{12}O_2$	Propyl propionate	20	1.921	0.5			(265)
$C_6H_{12}O_2$	Paraldehyde	0	1.825	1			(250)
$C_6H_{14}$	<i>n</i> -Hexane	0-50	2.205	0.4			(163)
		20-100	2.511	1			(250)
$C_6H_{14}O_2$	Acetal	0	1.954	1			(250)
		19-99	2.1754	0.5			(152)
$C_6H_{13}N$	Dipropylamine	22-100	2.498	0.5			(133)
$C_7H_5ClO_2$	<i>o</i> -Chlorobenzoic acid	0	(1.639)	1	1.50	M. P. to 340	(4)
$C_7H_5ClO_2$	<i>m</i> -Chlorobenzoic acid	0	(1.115)	1	4.01	M. P. to 359	(4)
$C_7H_5ClO_2$	<i>p</i> -Chlorobenzoic acid	M. P.	2.290	1	0.0	M. P. to 505	(4)
$C_7H_5N$	Benzonitrile	22-186	1.846	0.5			(153)
$C_7H_5NO_4$	<i>o</i> -Nitrobenzoic acid	0	(1.315)	1	2.5	M. P. to 386	(4)
$C_7H_5NO_4$	<i>m</i> -Nitrobenzoic acid	0	(1.695)	1	2.4	M. P. to 366	(4)
$C_7H_5NO_4$	<i>p</i> -Nitrobenzoic acid	M. P.	1.878	1	0.0	M. P. to 484	(4)
$C_7H_5N_3O_6$	2, 4, 6-Trinitrotoluene	?	1.402	0.4			(75)
$C_7H_6O$	Benzaldehyde	22-172	1.792	0.5			(152)
$C_7H_6O_2$	Salicylaldehyde	18	1.599	0.5			(310)
$C_7H_6O_2$	Benzoic acid	0	(1.774)	1	3.22	M. P. to 322	(4)



Formula	Name	<i>t</i> or $\Delta t$ , °C	<i>c<sub>p</sub></i> , joule/g	± %	10 <sup>3</sup> <i>a</i>	Range, °C	Lit.
C <sub>7</sub> H <sub>7</sub> Cl	Benzyl chloride.....	0	1.350	0.5	3.10	10-140	(266)
C <sub>7</sub> H <sub>7</sub> Cl	Chlorotoluene.....	0	1.322	0.5	3.10	10-140	(266)
C <sub>7</sub> H <sub>7</sub> NO <sub>2</sub>	<i>o</i> -Aminobenzoic acid.....	M. P.	1.82	2	0.0	M. P. to 305	(4)
C <sub>7</sub> H <sub>7</sub> NO <sub>2</sub>	<i>m</i> -Aminobenzoic acid.....	M. P.	1.82	2	0.0	M. P. to 360	(4)
C <sub>7</sub> H <sub>7</sub> NO <sub>2</sub>	<i>p</i> -Aminobenzoic acid.....	M. P.	1.86	2	0.0	M. P. to 378	(4)
C <sub>7</sub> H <sub>8</sub>	Toluene.....	<i>v. p.</i> 115					
C <sub>7</sub> H <sub>8</sub> O	Benzyl alcohol.....	20-100	2.139	1.0			(250)
C <sub>7</sub> H <sub>8</sub> O	<i>o</i> -Cresol.....	22-200	2.261	0.5			(152)
C <sub>7</sub> H <sub>8</sub> O	<i>m</i> -Cresol.....	0-20	2.088	0.5			(45)
C <sub>7</sub> H <sub>8</sub> O	<i>p</i> -Cresol.....	21-197	2.314	0.5			(152)
C <sub>7</sub> H <sub>8</sub> O	Phenyl methyl ether.....	0-20	2.005	0.5			(45)
C <sub>7</sub> H <sub>8</sub> O	Phenyl methyl ether.....	0	1.697	0.5	3.60	10-140	(266)
C <sub>7</sub> H <sub>8</sub> O	Phenyl methyl ether.....	20-152	2.021	0.5			(155)
C <sub>7</sub> H <sub>8</sub> O <sub>2</sub>	Dimethylpyrone.....	166	2.3	10.0			(237)
C <sub>7</sub> H <sub>8</sub> N	Methylaniline.....	20-197	2.145	0.5			(155)
C <sub>7</sub> H <sub>8</sub> N	<i>o</i> -Toluidine.....	0	1.900	1			(250)
C <sub>7</sub> H <sub>8</sub> N	<i>o</i> -Toluidine.....	22-195	2.193	0.5			(155)
C <sub>7</sub> H <sub>8</sub> N	<i>o</i> -Toluidine.....	40.5	2.084	0.5			(139)
C <sub>7</sub> H <sub>8</sub> N	<i>o</i> -Toluidine.....	0	1.969	0.5	2.93	12-139	(265)
C <sub>7</sub> H <sub>8</sub> N	<i>o</i> -Toluidine.....	43	2.503	1			(20)
C <sub>7</sub> H <sub>8</sub> N	<i>o</i> -Toluidine.....	58	2.653	1			(20)
C <sub>7</sub> H <sub>8</sub> N	<i>o</i> -Toluidine.....	94	2.231	1			(267)
C <sub>7</sub> H <sub>10</sub> O	<i>o</i> -Methylcyclohexanone.....	15-18	1.825	0.5			(119)
C <sub>7</sub> H <sub>10</sub> O	<i>m</i> -Methylcyclohexanone.....	15-18	1.846	0.5			(119)
C <sub>7</sub> H <sub>10</sub> O	<i>p</i> -Methylcyclohexanone.....	15-18	1.846	0.5			(119)
C <sub>7</sub> H <sub>12</sub> O <sub>2</sub>	Allyl butyrate.....	20	1.887	0.5	3.68	10-140	(266)
C <sub>7</sub> H <sub>12</sub> O <sub>2</sub>	Allyl isobutyrate.....	20	1.875	0.5	3.68		
C <sub>7</sub> H <sub>12</sub> O <sub>4</sub>	Diethyl malonate.....	20	1.812	0.5	2.76		
C <sub>7</sub> H <sub>14</sub>	Heptylene (B. P., 98°).....	0-50	2.042	0.4			(163)
C <sub>7</sub> H <sub>14</sub> O	<i>o</i> -Hexahydrocresol.....	15-18	1.749	0.5			(119)
C <sub>7</sub> H <sub>14</sub> O	<i>m</i> -Hexahydrocresol.....	15-18	1.766	0.5			(119)
C <sub>7</sub> H <sub>14</sub> O	<i>p</i> -Hexahydrocresol.....	15-18	1.770	0.5			(119)
C <sub>7</sub> H <sub>14</sub> O	Heptaldehyde.....	0	1.528	1.0			(250)
C <sub>7</sub> H <sub>14</sub> O	Dipropyl ketone.....	20-140	2.310	0.5			(152)
C <sub>7</sub> H <sub>14</sub> O <sub>2</sub>	Heptylic acid.....	9	2.335	0.5			(105)
C <sub>7</sub> H <sub>14</sub> O <sub>2</sub>	Isoamyl acetate.....	20	1.921	0.5	2.76	0-110	(265)
C <sub>7</sub> H <sub>14</sub> O <sub>2</sub>	Butyl propionate.....	20	1.921	0.5			(265)
C <sub>7</sub> H <sub>14</sub> O <sub>2</sub>	Ethyl valerate.....	20	1.921	0.5			(266)
C <sub>7</sub> H <sub>14</sub> O <sub>2</sub>	Propyl butyrate.....	20	1.921	0.5			(265)
C <sub>7</sub> H <sub>14</sub> O <sub>2</sub>	Propyl isobutyrate.....	20	1.921	0.5			(265)
C <sub>7</sub> H <sub>16</sub>	<i>n</i> -Heptane (B. P., 98°).....	0-50	2.122	0.4			(163)
C <sub>7</sub> H <sub>16</sub>	<i>n</i> -Heptane (B. P., 98°).....	20	2.051	0.5			(201)
C <sub>7</sub> H <sub>16</sub>	<i>n</i> -Heptane (B. P., 98°).....	30	2.168	0.2	5.94	30-80	(321)
C <sub>7</sub> H <sub>16</sub>	Isoheptane (B. P., 91°).....	0-50	2.097	0.4			(163)
C <sub>8</sub> H <sub>8</sub> Cl <sub>4</sub>	<i>o</i> -Xylene tetrachloride.....	15-40	1.004	1.0			(61)
C <sub>8</sub> H <sub>8</sub> Cl <sub>4</sub>	<i>p</i> -Xylene tetrachloride.....	15-40	1.013	1.0			(61)
C <sub>8</sub> H <sub>8</sub> Br <sub>2</sub>	<i>o</i> -Xylene dibromide.....	15-40	0.766	1.0			(61)
C <sub>8</sub> H <sub>8</sub> Br <sub>2</sub>	<i>m</i> -Xylene dibromide.....	15-40	0.770	1.0			(61)
C <sub>8</sub> H <sub>8</sub> Br <sub>2</sub>	<i>p</i> -Xylene dibromide.....	15-40	0.753	1.0			(61)
C <sub>8</sub> H <sub>8</sub> Cl <sub>2</sub>	<i>o</i> -Xylene dichloride.....	15-40	1.184	1.0			(61)
C <sub>8</sub> H <sub>8</sub> Cl <sub>2</sub>	<i>m</i> -Xylene dichloride.....	15-40	1.235	1.0			(61)
C <sub>8</sub> H <sub>8</sub> Cl <sub>2</sub>	<i>p</i> -Xylene dichloride.....	15-40	1.180	1.0			(61)
C <sub>8</sub> H <sub>8</sub> O	Acetophenone.....	20-196	1.984	0.5			(153)
C <sub>8</sub> H <sub>8</sub> O <sub>2</sub>	<i>o</i> -Toluic acid.....	0	(1.766)	1.0	3.1	M. P. to 304	(4)
C <sub>8</sub> H <sub>8</sub> O <sub>2</sub>	<i>m</i> -Toluic acid.....	0	(2.107)	1.0	1.72	M. P. to 279	(4)
C <sub>8</sub> H <sub>8</sub> O <sub>2</sub>	<i>p</i> -Toluic acid.....	0	(1.324)	1.0	5.8	M. P. to 405	(4)
C <sub>8</sub> H <sub>8</sub> O <sub>2</sub>	Methyl benzoate.....	0	1.519	0.5	3.14	10-140	(266)
C <sub>8</sub> H <sub>8</sub> O <sub>2</sub>	Hydroxyacetanilide.....	0	(1.654)	1.0	3.32	M. P. to 231	(4)
C <sub>8</sub> H <sub>10</sub>	Ethylbenzene.....	0	1.645	0.5			(265)
C <sub>8</sub> H <sub>10</sub>	Ethylbenzene.....	30	1.711	0.2	3.71	20-70	(321)
C <sub>8</sub> H <sub>10</sub>	<i>o</i> -Xylene.....	39.6	1.883	0.5			(139)
C <sub>8</sub> H <sub>10</sub>	<i>o</i> -Xylene.....	30	1.721	0.2	3.24	30-80	(321)
C <sub>8</sub> H <sub>10</sub>	<i>o</i> -Xylene.....	0	1.605	0.5	4.36	10-110	(266)
C <sub>8</sub> H <sub>10</sub>	<i>m</i> -Xylene.....	9-40	1.674	0.5			(139)
C <sub>8</sub> H <sub>10</sub>	<i>m</i> -Xylene.....	16-35	1.620	0.5			(139)



Formula	Name	$t$ or $\Delta t$ , °C	$c_p$ , joule/g	$\pm$ %	$10^3 a$	Range, °C	Lit.
$C_8H_{10}$	<i>m</i> -Xylene (Cont'd)	30	1.678	0.2	3.40	30-80	(321)
		0	1.603	0.5	4.36	10-110	(266)
$C_8H_{10}$	<i>p</i> -Xylene	40.8	1.791	0.5			(139)
		30	1.663	0.2	3.89	10-140	(321)
$C_8H_{10}O$	<i>p</i> -Cresyl methyl ether	0	1.697	0.5	3.60	10-140	(266)
$C_8H_{10}O$	Phenetole	20	1.867	0.5	3.60	10-140	(266)
$C_8H_{10}O_4$	Diallyl oxalate	20	1.783	0.5	2.76	10-140	(266)
$C_8H_{11}N$	Dimethylaniline	0-20	1.749	0.5			(45)
		0	1.695	0.1	3.85	20-100	(142, 250, 266)
$C_8H_{14}O_2$	Allyl valerate	20	1.887	0.5	3.68	0-140	(266)
$C_8H_{14}O_4$	Diethyl succinate	20	1.892	0.5	2.76	0-140	(266)
$C_8H_{14}O_4$	Di- <i>n</i> -propyl oxalate	20	1.812	0.5	2.76	0-140	(266)
$C_8H_{14}O_4$	Diethyl malate	24-186	1.989	0.5			(152)
$C_8H_{16}$	Octylene	0-50	2.034	0.4			(163)
$C_8H_{16}O$	Methyl hexyl ketone	22-168	2.311	0.5			(152)
$C_8H_{16}O_2$	Isoamyl propionate	20	1.921	0.5			(265)
$C_8H_{16}O_2$	Butyl butyrate	20	1.921	0.5			(265)
$C_8H_{16}O_2$	Isobutyl butyrate	20	1.921	0.5			(265)
$C_8H_{16}O_2$	Propyl valerate	20	1.921	0.5			(265)
$C_8H_{18}$	<i>n</i> -Octane	0-50	2.113	0.4			(163)
		20-123	2.420	0.5			(152)
$C_8H_{19}N$	Diisobutylamine	22-130	2.390	0.5			(133)
$C_8H_{20}SiO_4?$	Ethyl silicate	15-98	1.783	0.5			(206)
$C_9H_7N$	Quinoline	0-20	1.473	0.5			(45)
$C_9H_{10}$	Benzylethylene	0	1.644	0.5	4.36	0-140	(266)
$C_9H_{10}O_2$	Ethyl benzoate	20	1.628	0.5	3.14	0-140	(266)
$C_9H_{12}$	Mesitylene	0	1.643	0.5	4.36	10-80	(266)
$C_9H_{12}$	Propylbenzene	0	1.674	0.5	4.365	6-60	(265)
$C_9H_{12}$	Pseudocumene	20	1.733	0.5	4.35		(266)
$C_9H_{12}O$	Ethyl <i>p</i> -cresyl ether	0	1.795	0.5	3.60		(266)
$C_9H_{12}O$	Propyl phenyl ether	0	1.795	0.5	3.60	10-140	(266)
$C_9H_{12}N$	Dimethyl- $\alpha$ -toluidine	21-185	2.072	0.5			(155)
$C_9H_{14}O_4$	Dipropyl malonate	20	1.812	0.5	2.76		(266)
$C_9H_{16}$	Nonylene	0-50	2.030	0.4			(163)
$C_9H_{16}O_2$	Isoamyl butyrate	20	1.921	0.5			(265)
$C_9H_{16}O_2$	Butyl valerate	20	1.921	0.5			(265)
$C_9H_{16}O_2$	Isoamyl isobutyrate	20	1.921	0.5			(265)
$C_9H_{20}$	Nonane	0-50	2.105	0.4			(163)
$C_{10}H_7NO_2$	$\alpha$ -Nitronaphthalene	58.6	1.528	0.5			(55)
		61.4	1.581	0.5			(55)
		94.3	1.632	0.5			(267)
$C_{10}H_8$	Naphthalene	87.5	1.684	1.0			(20)
		0	(1.310)	1.0	3.52	M. P. to 280	(4)
$C_{10}H_8O$	$\alpha$ -Naphthol	0	(1.626)	1.0	3.19	M. P. to 275	(4)
$C_{10}H_8O$	$\beta$ -Naphthol	0	(1.688)	1.0	2.61	M. P. to 236	(4)
$C_{10}H_9N$	$\alpha$ -Naphthylamine	53.2	1.988	0.5			(55)
		94.2	1.992	0.5			(267)
$C_{10}H_{10}$	Dihydronaphthalene	18-28	1.448				(258)
$C_{10}H_{10}O_2$	Allyl benzoate	20	1.624	0.5	3.14	10-140	(266)
$C_{10}H_{12}$	1, 2, 3, 4-Tetrahydronaphthalene	15-18	1.687	0.5			(119)
		23-233	2.139	0.5			(157)
$C_{10}H_{12}O$	Anethole	22.48	2.306	0.5			(191)
		24.59	2.360	0.5			(191)
		25.23	2.561	0.5			(191)
$C_{10}H_{12}O_2$	Propyl benzoate	20	1.666	0.5	3.14	0-140	(265)
$C_{10}H_{14}$	$\alpha$ -Cymene	0	1.674	0.5	4.36	10-140	(265)
$C_{10}H_{14}O$	Carvacrol	24-233	2.415	0.5			(156)
$C_{10}H_{14}O$	<i>ps</i> -Thymol	50	2.371	0.5			(19)
$C_{10}H_{14}O$	2, 4-Xylyl ethyl ether	0	1.745	0.5	3.60	10-140	(266)
$C_{10}H_{14}O_4$	Diallyl succinate	20	1.892	0.5	2.76	10-140	(266)
$C_{10}H_{16}N$	Diethylaniline	20	1.892	0.5	3.85	10-140	(266)
$C_{10}H_{18}$	<i>cis</i> -Decahydronaphthalene	15-18	1.653	0.5			(119)
$C_{10}H_{18}O_4$	Dibutyl oxalate	20	1.846	0.5			(266)
$C_{10}H_{18}O_4$	Dipropyl succinate	20	1.892	0.5	2.76	10-140	(266)
$C_{10}H_{20}$	Diamylene	20-130	2.281	0.5			(29)



Formula	Name	<i>t</i> or $\Delta t$ , °C	<i>c<sub>p</sub></i> , joule/g	± %	10 <sup>a</sup>	Range, °C	Lit.
C <sub>10</sub> H <sub>20</sub>	γ-Decylene.....	0-50	1.963	0.4			(163)
C <sub>10</sub> H <sub>20</sub> O <sub>2</sub>	Isoamyl valerate.....	20	1.921	0.5			(265)
C <sub>10</sub> H <sub>22</sub>	Decane (B. P., 159°).....	21-154	2.470	0.5			(152)
C <sub>10</sub> H <sub>22</sub>	Decane (B. P., 162°).....	0-50	2.072	0.4			(163)
C <sub>10</sub> H <sub>22</sub>	Decane (B. P., 172°).....	0-50	2.101	0.4			(163)
C <sub>10</sub> H <sub>22</sub>	Diisoamyl.....	21.5-155	2.469	0.5			(152)
C <sub>11</sub> H <sub>22</sub>	Undecylene.....	0-50	2.017	0.4			(163)
C <sub>11</sub> H <sub>24</sub>	Undecane.....	0-50	2.097	0.4			(163)
C <sub>12</sub> H <sub>10</sub> O	Diphenyl oxide.....	30	1.67				(73)
C <sub>12</sub> H <sub>11</sub> N	Diphenylamine.....	54	1.835	0.4			(55)
		56	1.851	0.4			(55)
		53	1.942	1.0			(20)
		66	2.017	1.0			(20)
C <sub>12</sub> H <sub>12</sub>	β-Dimethylnaphthalene.....	0	1.649	0.5			(257)
C <sub>12</sub> H <sub>22</sub> O <sub>4</sub>	Diisoamyl oxalate.....	20	1.879	0.5			(266)
C <sub>12</sub> H <sub>22</sub> O <sub>4</sub>	Isobutyl succinate.....	0	1.850	0.5	2.76	0-140	(265)
C <sub>12</sub> H <sub>24</sub>	Dodecylene.....	0-50	1.913	0.4			(163)
C <sub>12</sub> H <sub>24</sub> O <sub>2</sub>	Lauric acid.....	40-100	2.394	0.5			(105)
		57	2.155	0.5			(177)
C <sub>12</sub> H <sub>26</sub>	Dodecane.....	14-20	2.120	0.5			(16)
		0-50	2.093	0.4			(163)
C <sub>12</sub> H <sub>10</sub> O	β-Benzophenone.....	3-40	1.601	0.5			(195)
		0	1.448	0.5	6.49	0-40	(195)
C <sub>12</sub> H <sub>10</sub> O <sub>3</sub>	Salol.....	44.1	1.635	0.5			(55)
C <sub>13</sub> H <sub>26</sub>	Tridecylene.....	0-50	1.913	0.4			(163)
C <sub>13</sub> H <sub>28</sub>	Tridecane.....	0-50	2.088	0.4			(163)
C <sub>14</sub> H <sub>26</sub> O <sub>4</sub>	Isoamyl succinate.....	0	1.880	0.5			(262)
C <sub>14</sub> H <sub>28</sub>	Tetradecylene.....	0-50	1.896	0.4			(163)
C <sub>14</sub> H <sub>28</sub> O <sub>2</sub>	Myristic acid.....	56-100	2.256	0.5			(285)
C <sub>14</sub> H <sub>30</sub>	Tetradecane.....	0-50	2.080	0.4			(163)
C <sub>15</sub> H <sub>30</sub>	Pentadecylene.....	0-50	1.971	0.4			(163)
C <sub>15</sub> H <sub>32</sub>	Pentadecane.....	0-50	2.080	0.4			(163)
C <sub>16</sub> H <sub>32</sub> O <sub>2</sub>	Palmitic acid.....	65-104	2.733	0.5			(105)
C <sub>16</sub> H <sub>34</sub>	n-Hexadecane (B. P., 275°).....	0-50	2.076	0.4			(163)
C <sub>17</sub> H <sub>34</sub> O <sub>2</sub>	Betol.....	19-63	1.487	0.2			(195)
		0	(1.249)	0.2	5.58*	19-63	(195)
C <sub>18</sub> H <sub>36</sub> O <sub>2</sub>	Stearic acid.....	75-137	2.302	0.5			(105)

\* 10<sup>b</sup> = 5.61.

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## THE HEAT CAPACITY OF CERTAIN PURE LIQUIDS

J. H. AWBERY

## Hg, Mercury

Solid Hg (12, 69, 83, 138, 209, 235, 236, 243, 282)			Liquid Hg (10, 12, 18, 43, 48, 58, 123, 138, 186, 235, 236, 262, 322)		
<i>t</i> , °C	Joule/g-atom	± %	<i>t</i> , °C	Joule/g	± %
-270	0.221	1	-40	0.1452	0.1
-260	4.61	2	-20	0.1417	0.1
-240	16.95	0.5	0	0.14030	0.25
-220	21.27	0.5	+20	0.13934	0.25
-200	23.07	0.5	40	0.13864	0.25
-150	25.76	0.5	60	0.13814	0.25
-100	26.92	0.5	80	0.13780	0.25
-50	27.77	0.5	100	0.13757	0.1
-40	27.99	0.5			

H<sub>2</sub>O, Water

*c<sub>p</sub>* in joules per gram. NOTE.—The values in this table should be increased by 0.12 % to bring them into accord with the I. C. T. accepted value for the joule which is 4.185 cal<sub>15</sub>.

<i>t</i> , °C	<i>p</i> = 1 atm. (8, 9, 10, 11, 41, 42, 53, 54, 62, 72, 99, 101, 102, 104, 126, 127, 150, 214, 242, 259)			<i>p</i> = the vapor pressure (72, 104, 242)		
	<i>c<sub>p</sub></i>	± %	°C	<i>c<sub>p</sub></i>	± %	°C
-5	4.244	0.2	20	4.184	0.05	100
0	4.220	0.2	40	4.180	0.1	150
+5	4.210	0.2	60	4.186	0.1	200
10	4.199	0.1	80	4.192	0.2	250
15	4.190	0.1	100	4.198	0.2	300



CO<sub>2</sub>Liquid; values of  $c_p$  and  $c_v$ , joule/g,  $p$  in kg/cm<sup>2</sup>,  $v$  in cm<sup>3</sup>/g

$c_p \pm 5\%$ (67, 130, 162)							$c_v \pm 2\%$ (7, 71)						
$t, ^\circ\text{C}$ \diagdown $p$	40	65	$t, ^\circ\text{C}$ \diagdown $p$	65	90	115	$t, ^\circ\text{C}$ \diagdown $v$	1.1	$t, ^\circ\text{C}$ \diagdown $v$	2.66	$t, ^\circ\text{C}$ \diagdown $v$	2.66	
-50		1.94	0	2.15	2.08	2.00	0	1.00	30	5.08	80	5.74	
-40		2.00	+10	2.3	2.17	2.07	10	1.00	40	5.19	90	5.91	
-30		2.07	20	2.8	2.50	2.3	20	1.04	50	5.31	100	6.16	
-20	2.0	2.17	25	3.6	2.8	2.55	30	1.19	60	5.45	110	6.57	
-10	2.1	2.25	30		3.3	2.8	40	1.29	70	5.59	120	7.26	

## VARIATION OF SPECIFIC HEAT WITH PRESSURE

Values of (specific heat at 1 atm. — sp. ht. at  $p$ , kg/cm<sup>2</sup>)  $\pm 1\%$ ; joules per gram

Hg, Mercury (47, 158)

$p$ , kg/cm <sup>2</sup>	15°	64°	91°	$p$ , kg/cm <sup>2</sup>	15°	$p$ , kg/cm <sup>2</sup>	15°
0	0.0	0.0	0.0	1000	0.000062	5000	0.000246
200	0.00002	0.00046	0.00059	2000	0.000092	6000	0.000277
400	0.00005	0.00105	0.00129	3000	0.000154	7000	0.000338
600	0.00005	0.00146	0.00207	4000	0.000185		

CS<sub>2</sub>, CH<sub>3</sub>OH and C<sub>2</sub>H<sub>5</sub>OH (47, 158)

$p$ , kg/cm <sup>2</sup>	CS <sub>2</sub>				CH <sub>3</sub> OH				C <sub>2</sub> H <sub>5</sub> OH			
	20°	40°	60°	80°	20°	40°	60°	80°	20°	40°	60°	80°
0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
500												
1 000	-0.00043	+0.0022	+0.0078	+0.0170	+0.006	+0.008	+0.011	+0.012	-0.001	+0.004	+0.006	+0.006
2 000	-0.0078	+0.0004	+0.0100	+0.0310	+0.014	+0.011	+0.019	+0.026	-0.001	+0.008	+0.010	+0.004
3 000	-0.0091	-0.0019	+0.0095	+0.0378	-0.007	+0.008	+0.021	+0.026	-0.001	+0.013	+0.011	+0.001
4 000	-0.0061	-0.0013	+0.0077	+0.0382	-0.009	+0.006	+0.017	+0.023	-0.000	+0.014	+0.009	-0.001
5 000	-0.00174	-0.0022	+0.0062	+0.0313	-0.010	+0.004	+0.016	+0.018	+0.001	+0.011	+0.004	-0.003
6 000	+0.0052	-0.0044	+0.0054	+0.0205	-0.011	+0.003	+0.013	+0.016	+0.003	+0.008	+0.001	-0.003
7 000	+0.0118	-0.0074	+0.0017	+0.0144	-0.011	-0.003	+0.009	+0.017	+0.002	+0.004	-0.001	-0.001
8 000	+0.0104	-0.0096	-0.0017	+0.0131	-0.012	-0.007	+0.003	+0.023	+0.001	+0.001	-0.006	+0.004
9 000	+0.0035	-0.0135	-0.0039	+0.0162	-0.012	-0.011	-0.003	+0.033	-0.003	-0.009	-0.009	+0.031
10 000	-0.0022	-0.0214	-0.0050	+0.0220	-0.015	-0.014	-0.004	+0.051	-0.011	-0.013	-0.012	+0.057
11 000	-0.0017	-0.0264	-0.0065	+0.0229	-0.020	-0.015	-0.001	+0.059	-0.018	-0.013	-0.012	+0.055
12 000	+0.0017	-0.0245	-0.0078	+0.0112	-0.013	-0.013	+0.001	+0.035	-0.000	-0.013	-0.011	+0.003

Values of  $c_p$  for the Liquid State $p$  = the vapor pressureNH<sub>3</sub>

(7, 71, 74, 79, 135, 149, 210, 288)

$t, ^\circ\text{C}$	$c_p$ , joule/g	$\pm \%$
-60	4.383	0.1
-40	4.440	
-20	4.510	
0	4.597	
+20	4.710	
40	4.860	
60	5.084	
80	5.42	0.25
90	5.71	
100	6.19	0.5
110	6.72	1

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SO<sub>2</sub>

(56, 175, 232)

$t, ^\circ\text{C}$	$c_p$ , joule/g	$\pm \%$
-20	1.31	5
0	1.33	
+20	1.37	
40	1.43	

SO<sub>2</sub>—(Continued)

$t, ^\circ\text{C}$	$c_p$ , joule/g	$\pm \%$
60	1.51	
80	1.62	
100	1.75	
120	1.95	
140	2.38	
150	3.54	
11 to 140	1.37 +	0.5
	0.0012t	

H<sub>2</sub>SO<sub>4</sub>

(56, 175, 227, 228, 232)

$t, ^\circ\text{C}$	$c_p$ , joule/g	$\pm \%$
10 to 45	1.42 +	3
	0.0016t	

C<sub>2</sub>H<sub>5</sub>OH, Ethyl alcohol

(2, 21, 36, 40, 95, 111, 116, 122, 152, 187, 243, 247, 249, 273, 289, 301, 321)

$t, ^\circ\text{C}$	$c_p$ , joule/g	$\pm \%$
-100	1.91	0.5
-75	1.92	

C<sub>2</sub>H<sub>5</sub>OH.—(Continued)

$t, ^\circ\text{C}$	$c_p$ , joule/g	$\pm \%$
-50	1.98	
0	2.24	
+25	2.43	1
50	2.73	
100	3.45	3
150	4.41	

 $p$  = 1 atm.CH<sub>3</sub>OH, Methyl alcohol

(40, 111, 139, 144, 275, 301)

$t, ^\circ\text{C}$	$c_p$ , joule/g	$\pm \%$
0	2.37	1
20	2.51	
40	2.58	

C<sub>3</sub>H<sub>7</sub>OH, Propyl alcohol

Normal (40, 95, 139, 152, 187, 247, 301)

$t, ^\circ\text{C}$	$c_p$ , joule/g	$\pm \%$
-120	1.80	1
-100	1.82	
-50	1.91	
-25	2.01	
0	2.20	
+25	2.45	
50	2.74	

C<sub>3</sub>H<sub>7</sub>OH.—(Continued)

Iso- (152, 187, 219, 321)

$t, ^\circ\text{C}$	$c_p$ , joule/g	$\pm \%$
-100	1.78	3
-50	1.98	
0	2.36	
+50	3.10	

CS<sub>2</sub>, Carbon disulfide

(21, 89, 111, 122, 138, 289)

$t, ^\circ\text{C}$	$c_p$ , joule/g	$\pm \%$
-100 to +150	0.984 +	6 at extremes, 3 at 0
	0.00103t	

C<sub>2</sub>H<sub>3</sub>O<sub>2</sub>, Acetic acid

(23, 28, 105, 148, 153, 176, 178, 192, 219, 249, 265, 301)

$t, ^\circ\text{C}$	$c_p$ , joule/g	$\pm \%$
0 to 80	1.960 +	2
	0.00389t	

C<sub>3</sub>H<sub>8</sub>O<sub>3</sub>, Glycerol

(28, 80, 93, 166, 282, 283)

Liquid and vitreous

$t, ^\circ\text{C}$	$c_p$ , joule/g	$\pm \%$
-260	0.18	5
-200	0.46	
-150	0.73	2



$C_2H_5O_2$ —(Continued)			$C_6H_6$ , Benzene		
$t, ^\circ C$	$c_p$ , joule/g	$\pm \%$	(4, 23, 65, 89, 116, 182, 232, 247, 265, 267, 275, 301, 302, 321)		
-100	0.97		$t, ^\circ C$	$c_p$ , joule/g	$\pm \%$
-95	1.00		5	1.63	2
?U			10	1.65	
-85	1.89		20	1.70	
-50	2.03		40	1.77	
0	2.26		60	1.86	
+50	2.51	5			
100	2.80				

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$C_6H_6$ —(Continued)			$C_7H_8$ —(Continued)		
$t, ^\circ C$	$c_p$ , joule/g	$\pm \%$	$t, ^\circ C$	$c_p$ , joule/g	$\pm \%$
80	1.94		80	1.869	
90	1.98		100	1.966	
$C_7H_8$ , Toluene			$C_6H_7N$ , Aniline*		
(21, 23, 81, 89, 116, 224, 249, 265, 281, 301, 302, 321)			(15, 92, 100, 111, 139, 156, 224, 231, 266, 267, 301)		
-97	1.472	1	0	2.00	5
-50	1.522		50	2.18	
0	1.614		100	2.29	
+50	1.761		* For more recent data, v. (324).		

## THE HEAT CAPACITY OF CERTAIN SOLUTIONS

J. H. AWBERY

## AQUEOUS SOLUTIONS

## ACIDS

(M = Mole)

 $HCl$  (57, 176, 251, 252, 253, 295, 296, 304, 309)

M % $HCl$	$\frac{M_{HCl}}{M_{H_2O}}$	Joule/g $\pm \frac{1}{4} \%$				
		0°C	10°C	20°C	40°C	60°C
0.0	0.0	4.215	4.195	4.182	4.174	4.182
4.76	.05	3.446	3.446	3.521	3.532	3.265
9.09	.10	3.015	3.015	3.132	3.141	3.272
13.0	.15	2.743	2.714	2.852	2.879	2.974
16.7	.20	2.560	2.526	2.643	2.701	2.798
20.0	.25	2.430	2.413	2.476	2.576	2.677
23.1	.30	2.346	2.338	2.350	2.488	2.605
25.9	.35	2.300				2.551

 $H_2SO_4$  (35, 56, 111, 175, 221, 232, 233, 268)

M % $H_2SO_4$	$\frac{M_{H_2O}}{M_{H_2SO_4}}$	Joule/g		M % $H_2SO_4$	$\frac{M_{H_2O}}{M_{H_2SO_4}}$	Joule/g $\pm \frac{1}{4} \%$ , 18°C
		$\pm \frac{1}{4} \%$ , 18°C	$\pm \frac{1}{2} \%$ , 35°C			
100.0	0	1.397	1.414	0.99	100	4.002
16.7	5	2.417	2.242	0.66	150	4.048
9.09	10	2.999	2.59	0.497	200	4.077
4.76	20	3.467	2.97	0.0	$\infty$	4.182
3.23	30	3.663	3.26			
2.44	40	3.780	3.43			
1.96	50	3.860	3.53			
1.64	60	3.911	3.60			

 $C_2H_3O_2$ , Acetic acid, 38°C (176, 235, 249)

M % $HAc$	0.0	3.23	6.98	16.7	30.9	54.5	100.0
Joule/g	4.17	4.01	3.81	3.44	3.05	2.64	2.24

## ALKALIES

 $NH_3$  (295, 309)

M % $NH_3$	$\frac{M_{NH_3}}{M_{H_2O}}$	Joule/g $\pm \frac{1}{2} \%$			
		2.4°C	20.6°C	41°C	61°C
0.0	0	4.211	4.182	4.174	4.182
5.2	5	4.148	4.186	3.998	4.216
10.5	10	4.098	4.170	4.441	4.261
15.8	15	4.073	4.144	4.354	4.303
20.9	20	4.023	4.144	4.308	
26.1	25	4.006	4.165		
31.2	30	4.002	4.197		
36.3	35	4.023	4.236		
41.4	40	4.124			

 $C_6H_5NH_2$ , Aniline, 20°C (15, 165)

M % $PhNH_2$	100	95.0	90.5	82.3	75.2
Joule/g $\pm 2 \%$	2.08	2.17	2.22	2.34	2.43

 $NaOH$ , 20°C (36, 110, 251, 252, 295, 296, 304)

M % $NaOH$	0.0	0.50	0.99	4.76	9.09
Joule/g $\pm 0.1 \%$	4.182	4.123	4.045	3.701	3.498

M % $NaOH$	16.7	23.1	28.6	37.5
Joule/g $\pm 0.1 \%$	3.341	3.287	3.275	3.270

 $KOH$  (110, 251, 252, 295, 296)

M % $KOH$	Joule/g		M % $KOH$	Joule/g $\pm 0.1 \%$ , 19°C	M % $KOH$	Joule/g $\pm 0.1 \%$ , 19°C
	$\pm 0.1 \%$ , 19°C	$\pm 0.5 \%$ , 27°C				
9.09	3.132	3.26	1.64	3.894	0.497	4.077
4.76	3.396	3.51	1.23	3.956	0.333	4.094
2.44	3.764	3.81	0.99	3.998	0.249	4.103
					0.0	4.182

## SALTS

 $NaCl$  (43, 66, 103, 176, 239, 252, 273, 294, 295, 322)

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M % $NaCl$	$\frac{M_{H_2O}}{M_{NaCl}}$	Joule/g $\pm 0.1 \%$			
		6°C	20°C	33°C	57°C
9.09	10	3.37	3.38	3.39	3.41
6.25	15	3.457	3.468	3.472	3.52
4.76	20	3.572	3.593	3.604	3.64
2.44	40	3.809	3.822	3.834	3.86
1.64	60	3.910	3.922	3.934	
1.23	80	3.969	3.980	3.988	
0.99	100	4.011	4.020	4.021	
0.66	150	4.054	4.062	4.068	
0.497	200	4.092	4.092	4.093	
0.333	300		4.113		
0.249	400		4.14		

$t, ^\circ C$	$d_4^t$	Joule/g $\pm 1 \%$	Lit.
-15	1.114	3.20	(69)
-25	1.26	2.71	

 $KCl$  (43, 128, 176, 181, 239, 252, 273, 294, 295, 296, 322)

M % $KCl$	$\frac{M_{KCl}}{M_{H_2O}}$	Joule/g $\pm 0.1 \%$			
		6°C	20°C	33°C	40°C
0.0	0.0	4.202	4.180	4.170	4.17
0.99	0.01	3.954	3.958	3.962	3.96
1.96	0.02	3.771	3.772	3.788	3.78
2.91	0.03	3.611	3.622	3.633	3.64
3.85	0.04	3.461	3.478	3.492	3.50
4.76	0.05	3.337	3.351	3.367	3.35
5.66	0.06	3.222	3.238	3.254	3.24
6.54	0.07	3.12	3.138	3.16	3.13
7.41	0.08		3.036		



## ALCOHOLS

B = CH<sub>3</sub>OH, Methyl alcohol (40, 144)

M % B	Joule/g $\pm \frac{1}{4}\%$			M % B	Joule/g $\pm \frac{1}{4}\%$		
	5°	20°	40°		5°	20°	40°
0.0	4.184	4.182	4.176	36.0	3.454	3.626	3.668
2.87	4.270	4.195	4.170	45.8	3.245	3.387	3.471
5.88	4.253	4.186	4.163	56.7	3.045	3.166	3.266
9.03	4.174	4.157	4.136	69.6	2.852	2.957	3.040
12.3	4.077	4.113	4.107	83.5	2.643	2.727	2.831
19.4	3.872	4.015	4.015	100.0	2.413	2.509	2.580
27.3	3.668	3.835	3.856				

B = C<sub>2</sub>H<sub>5</sub>OH, Ethyl alcohol (36, 40, 52, 164, 165, 273, 323)

M % B	Joule/g		
	$\pm 0.5\%$ , 3°C	$\pm 0.5\%$ , 23°C	$\pm 1\%$ , 41°C
0.0	4.211	4.182	4.174
2.02	4.316	4.236	4.241
4.16	4.379	4.274	4.291
6.46	4.395	4.312	4.320
8.91	4.362	4.324	4.324
11.5	4.282	4.299	4.299
14.4	4.186	4.241	4.257
20.7	3.925	4.077	4.107
28.1	3.622	3.847	3.898
37.0	3.367	3.588	3.655
47.7	3.132	3.329	3.404
61.0	2.802	3.040	3.132
77.9	2.568	2.760	2.861
100.0	2.263	2.417	2.601

B = C<sub>3</sub>H<sub>7</sub>OH, n-Propyl alcohol (40, 213)

M % B	Joule/g $\pm \frac{1}{4}\%$			M % B	Joule/g $\pm \frac{1}{4}\%$		
	5°	20°	40°		5°	20°	40°
0.0	4.203	4.182	4.174	16.7	3.990	4.044	3.986
1.55	4.308	4.282	4.231	23.1	3.668	3.772	3.810
3.23	4.395	4.383	4.280	31.0	3.404	3.521	3.617
5.03	4.466	4.441	4.312	41.2	3.128	3.254	3.408
6.97	4.538	4.466	4.320	54.5	2.852	2.973	3.203
9.09	4.517	4.441	4.253	73.0	2.559	2.695	2.961
11.4	4.329	4.329	4.165	100.0	2.233	2.384	2.601

B = C<sub>3</sub>H<sub>8</sub>O<sub>3</sub>, Glycerol (35, 80, 166)

M % B	Joule/g $\pm \frac{1}{2}\%$		M % B	Joule/g $\pm \frac{1}{2}\%$	
	15°C	32°C		15°C	32°C
0.0	4.18	4.17	22.7	3.20	3.17
2.12	4.03	4.02	43.9	2.80	2.81
4.66	3.88	3.86	100.0	2.32	2.41
11.5	3.56	3.52			

## NON-AQUEOUS SOLUTIONS

 $c_p$  = joule/g

CS <sub>2</sub>		CH <sub>4</sub> O		B = C <sub>3</sub> H <sub>8</sub> O	
B = CH <sub>4</sub> O		B = C <sub>2</sub> H <sub>5</sub> O		n-Propyl alcohol	
$\pm 3\%$ (52)		$\pm 0.5\%$ (40)		$\pm 0.5\%$ (139)	
$t = 20^\circ\text{C}$		$t = 25^\circ\text{C}$		$t = 40^\circ\text{C}$	
M % A	$c_p$	M % A	$c_p$	M % A	$c_p$
100.0	1.02	100.0	2.530	100.0	2.580
55.8	1.51	85.2	2.518	81.7	2.526
29.5	1.97	68.3	2.501	65.2	2.530
12.3	2.26	48.9	2.493	38.5	2.559
0.0	2.51	26.4	2.467	0.0	2.601
		0.0	2.430		

C<sub>2</sub>H<sub>5</sub>OB = C<sub>2</sub>H<sub>5</sub>O

n-Propyl alcohol

Solid,  $\pm 2\%$  (95)

50 M % A

°C

-200 0.92

-190 1.02

-180 1.11

Liquid,  $\pm 0.5\%$ 

-75 1.865

-50 2.003

-25 2.112

0 2.196

B = NaCl.200H<sub>2</sub>O $\pm 1\%$  (136) $t = 20^\circ\text{C}$ 

M % A\*

0.0 4.08

89.8 4.20

95.2 4.27

97.2 4.20

98.2 4.03

99.2† 3.51

99.7† 2.96

100.0 2.38

\* M % A = moles  
C<sub>2</sub>H<sub>5</sub>O/(moles C<sub>2</sub>H<sub>5</sub>O +  
moles salt).†  $\pm 1$ . ‡  $\pm 2$ .B = KCl.200H<sub>2</sub>O $\pm 1\%$  (136) $t = 58^\circ\text{C}$ 

0.0 4.04

89.9 4.18

95.2 4.23

97.2 4.16

98.2 3.98

99.2 3.63

99.7 3.15

100.0 2.84

B = C<sub>2</sub>H<sub>5</sub>N

Aniline

 $\pm 0.5\%$  (139) $t = 40^\circ\text{C}$ 

0.0 2.13

34.1 2.38

60.8 2.62

B = C<sub>6</sub>H<sub>7</sub>N—

(Cont'd)

M % A

82.3 2.79

86.1 2.81

93.4 2.81

100.0 2.60

C<sub>3</sub>H<sub>8</sub>O<sub>3</sub>

Glycerol

B = C<sub>6</sub>H<sub>7</sub>N

Aniline

 $\pm 0.5\%$  (166) $t = 20^\circ\text{C}$ 

0.0 2.15

5.1 2.24

10.1 2.31

20.2 2.41

30.2 2.47

C<sub>4</sub>H<sub>10</sub>O

Ether

B = C<sub>6</sub>H<sub>6</sub>, Benzene $\pm 2\%$  (275)

M %

A

100 2.24 2.36

75 2.18 2.30

50 2.10 2.21

25 1.99 2.07

0 1.69 1.77

## LITERATURE

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## THE HEAT CAPACITY OF ALLOYS, AMALGAMS AND INTERMETALLIC COMPOUNDS

LUIGI ROLLA

## CONTENTS

Ferrous alloys.  
Amalgams.  
Non-ferrous alloys.

## SYMBOLS

$C_p$  (resp.  $C_m$ ) True (resp. mean) heat capacity at  $t$ , °C (resp.  $t_1$  to  $t_2$ , °C), in joules per gram-molecular weight per deg C.

$c_p$  (resp.  $c_m$ ) True (resp. mean) specific heat at  $t$ , °C (resp.  $t_1$  to  $t_2$ , °C), in joules per gram per deg C.

## ARRANGEMENT

In each part the alloys are arranged in alphabetical order according to the chemical symbols of the elements which they contain. Thus, Cu-Al alloys will be found under Al; but Cu-Sn alloys will be found under Cu, Zn-Sn alloys under Sn, etc.

## MATIÈRES

Métaux ferreux.  
Amalgames.  
Alliages non ferreux.

## SYMBOLES

$C_p$  (resp.  $C_m$ ) Capacité calorifique vraie (resp. moyenne) à  $t$ , °C (resp.  $t_1$  à  $t_2$ , °C) en joules par poids moléculaire gramme et par degré C.

$c_p$  (resp.  $c_m$ ) Chaleur spécifique vraie (resp. moyenne) à  $t$ , °C (resp.  $t_1$  à  $t_2$ , °C) en joules par gramme par degré C.

## ARRANGEMENT

Dans chaque partie, les alliages sont arrangés dans l'ordre alphabétique en accord avec les symboles chimiques des éléments qu'ils contiennent. Ainsi les alliages Cu-Al seront trouvés sous Al alors que les alliages Cu-Sn seront trouvés sous Cu et les alliages Zn-Sn sous Sn, etc.

## INHALTSVERZEICHNIS

Eisenlegierungen.  
Amalgame.  
Eisenfreie Legierungen.

## ZEICHEN

$C_p$  (bezw.  $C_m$ ) Wahre (bezw. mittlere) Wärmeinhalt bei  $t$ , °C (bezw.  $t_1$  bis  $t_2$ , °C) in Joule pro Gramm-Molekulargewicht pro °C.

$c_p$  (bezw.  $c_m$ ) Wahre (bezw. mittlere) spezifische Wärme bei  $t$ , °C (bezw.  $t_1$  bis  $t_2$ , °C) in Joule pro Gramm pro °C.

## ANORDNUNG

In jedem Teil sind die Legierungen nach dem Alphabet geordnet und zwar nach den chemischen Symbolen der sie zusammensetzenden Elemente. So wird man Cu-Al-Legierungen bei Al finden, aber Cu-Sn-Legierungen bei Cu dann Zn-Sn-Legierungen unter Sn und so fort.

## INDICE

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Leghe non contenenti ferro 119

## SIMBOLI

$C_p$  (o  $C_m$ ) Calore specifico vero (o medio) a  $t$ , °C (o fra  $t_1$  e  $t_2$ , °C) espresso in joule per grammo molecola.

$c_p$  (o  $c_m$ ) Calore specifico vero (o medio) a  $t$ , °C (o fra  $t_1$  e  $t_2$ , °C) espresso in joule per grammo.

## DISPOSIZIONE

Le leghe sono disposte in ordine alfabetico secondo i simboli chimici degli elementi in esse contenuti. Per esempio, la lega Cu-Al si trova sotto Al; la lega Cu-Sn si trova sotto Cu, la lega Zn-Sn sotto Sn, ecc.

## FERROUS ALLOYS

## Fe-C

*v. also* Vol. II, p. 518

$c_m(17-100^\circ) = 0.4661 + 0.0184 \times \% C$  (From 0 to 7%) (14)

% C	17-250°	0.17	0.35	0.81	1.00	1.43	4.13
$c_m$ (14)		0.4956	0.4985	0.5056	0.5119	0.5215	0.5818
% C	17-400°	0.11	0.45	0.89	1.22	1.54	4.06
$c_m$ (14)		0.5207	0.5249	0.5362	0.5425	0.5445	0.5919
% C	17-500°	0.17	0.45	0.89	1.22	1.54	4.06
$c_m$ (14)		0.5471	0.5475	0.5579	0.5592	0.5617	0.6002
% C	17-550°	0.17	1.54	4.06			
$c_m$ (14)		0.5517	0.5551	0.6019			
% C	17-640°	0.17	0.45	0.89	1.22	1.54	4.06
$c_m$ (14)		0.5747	0.5772	0.5839	0.5856	0.5868	0.6090
% C	17-680°	0.11	0.89	1.00	4.06		
$c_m$ (14)		0.5902	0.5969	0.5985	0.6165		

0.5% C;  $c_m(-186$  to  $+18^\circ) = 0.3570$ ;  $(18-100^\circ) = 0.4730$  (1).  
For higher temps., *v.* Fig. 2.

Fe<sub>3</sub>C, Cementite (14); Mol. wt. = 179.52

$t$ , °C.....	100	250	400	525	640	680
$c_m$ (17- $t$ ).....	106.0	114.4	114.7	114.4	113.5	113.8

0.09% C;  $c = 0.4889$  (tempered from 850°C in H<sub>2</sub>O); = 0.4922 (annealed 24 hr at 650°C) (10).

% C (10).....	0.29	0.50	0.70	0.89	1.05	1.48
$c$ (normalized).....	0.4818	0.4872	0.4939	0.4989	0.5039	0.5136
$c$ (annealed).....	0.4801	0.4788	0.4885	0.4964		0.5078

Cast iron (annealed in minutes at 670°C) (10)

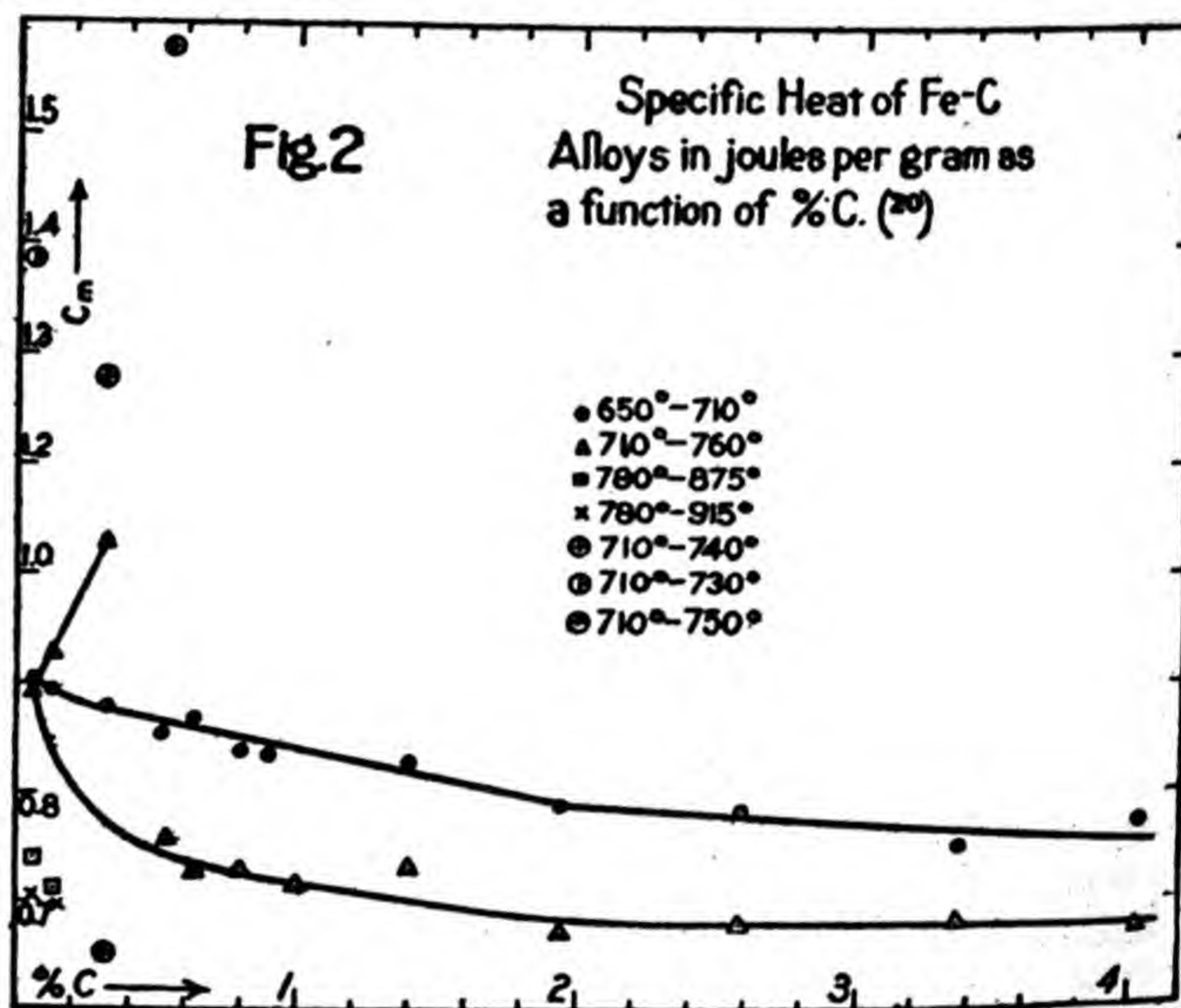
m.....	0	5	10	60
$c$ .....	0.5739	0.5630	0.5508	0.4847

## Fe-Ni, Ferronickel

30% Fe;  $c_p = 0.4696$  at 100°C (5).

## Fe-Sb

55% Fe;  $c_m$  (0-100°) = 0.3637 (12).



## Fe-Si

% Fe (23).....	90	86	50	25	15	5
$c_m$ (0-41°).....	0.543	0.553	0.606	0.655	0.673	0.692

FeSi (24); Mol. wt. = 83.9

$t$ , °C.....	17-100	100	200	300	400	500	600
$C$ .....	49.7 (32)	51.5	54.1	56.2	57.9	59.4	60.4

## Special Fe Alloys

Fe, 71.6 + Si, 1.7 + V, 26.7;  $c_m(15-100^\circ) = 0.496$  (18)

Invar { $t^\circ$ .....	-182 to -15	15-100	15-600	(36)
$c_m$ .....	0.3876	0.5028	0.5274	



C, 1.25 + Mn, 0.62 + Si, 0.46;  $c_p(12^\circ) = 0.513$  (3).C, 0.7 + Mn, 0.82 + Ni, 31.4;  $c_p(12^\circ) = 0.506$  (3).C, 0.6 + Mn, 5.04 + Ni, 25.0;  $c_p(12^\circ) = 0.496$  (3).C, 0.76 + Mn, 0.28 + W, 11.5;  $c_p(12^\circ) = 0.436$ .C, 0.26 + Si, 5.50;  $c_p(12^\circ) = 0.450$  (3).C, 1.09 + Cr, 9.50;  $c_p(12^\circ) = 0.505$  (3).C, 0.04 + Al, 1.0 + Cu, 3.75 + Mn, 0.16;  $c_p(12^\circ) = 0.491$  (3).

%	S	C	Cu	Mn	P	Si	$c_p^{18^\circ}$	$c_p^{100^\circ}$
	0.025	0.1	0.035	0.11	0.003	0.18	0.441	0.496 (11)

**Krupp Steel**

I. C, 0.01 + Mn, Tr. + P, 0.04 + S, 0.03 + Si, 0.02.

II. C, 0.06 + Mn, 0.05 + P, 0.005 + S, 0.019 + Si, 0.005.

$t^\circ$	250	300	350	400	450	500
$c_l(0-t^\circ)$ (7)	0.504	0.516	0.526	0.537	0.549	0.560
$c_{ll}(0-t^\circ)$ (22)	0.511	0.526	0.538	0.546	0.561	0.572
$t^\circ$	550	600	650	700	750	800
$c_l(0-t^\circ)$ (7)	0.570	0.584	0.600	0.622	0.643	0.669
$c_{ll}(0-t^\circ)$ (22)	0.584	0.593	0.612	0.667	0.701	0.711
$t^\circ$	850	900	950	1000	1050	1100
$c_l(0-t^\circ)$ (7)	0.689	0.688	0.675	0.652	0.633	0.642
$c_{ll}(0-t^\circ)$ (22)	0.711	0.711	0.707	0.702	0.699	0.697

**Ferromanganese (21)**C, 0.6 + Mn, 48 + Si, 21.9;  $c_m(-185 \text{ to } +20^\circ) = 0.446$ .**Ferronickel (9)**

C, 0.36 + Ni, 0.24 + Mn, 0.4

$t^\circ$	0-18	20-100	20-270
$c_m$ (magnetic)	0.4546	0.4939	0.5203
$c_m$ (non-magnetic)	0.4274	0.4713	0.5186

**AMALGAMS**

Formula or Wt. % Hg	$t$ or $\Delta t$ , $^\circ\text{C}$	$c_p$ or $c_m$ , joule/g	Lit.
<b>Hg-K</b>			
90.4	-22 to +15	0.1882	(35)
<b>Hg-Na</b>			
97	-22 to +15	0.2257	(35)
90	-21 to +15	0.1592	
<b>Hg-Zn</b>			
9.5	0 to 97	0.3765	(17)
20.1		0.3516	(17)
31.2		0.3403	(17)
37.2		0.3641	(17)
49.0		0.3457	(17)
61.2		0.3202	(17)
67.7		0.3055	(17)
79.7		0.2829	(17)
88.6		0.2688	(17)
HgZn	-27 to +15	0.2314	(35)
HgZn	15 to 89	0.2714	(35)
HgZn <sub>2</sub>	-32 to +15	0.2806	(35)
HgZn <sub>2</sub>	15 to 89	0.3276	(35)
<b>Hg-Pb</b>			
49.2	-30 to +15	0.1447	(35)
49.2	23 to 99	0.1605	(27)
49.2	15 to 89	0.1772	(35)
32.6	-25 to +15	0.1401	(35)
32.6	15 to 89	0.1358	(35)
12.2	-34 to +15	0.1276	(35)
12.2	15 to 89	0.1293	(35)
<b>Hg-Sn</b>			
10.0	0 to 97	0.2289	(17)
20.0	0 to 97	0.2243	(17)
30.0	0 to 97	0.2884	(17)

**Hg-Sn. —(Continued)**

Formula or Wt. % Hg	$t$ or $\Delta t$ , $^\circ\text{C}$	$c_p$ or $c_m$ , joule/g	Lit.
40.0	0 to 97	0.2875	(17)
50.0	0 to 97	0.2879	(17)
60.0	0 to 97	0.2867	(17)
70.0	0 to 97	0.2821	(17)
80.0	0 to 97	0.2691	(17)
90.0	0 to 97	0.2528	(17)
Hg <sub>2</sub> Sn	-23 to +15	0.1649	(35)
Hg <sub>2</sub> Sn	15 to 89	0.3101	(35)
HgSn	-30 to +15	0.1709	(35)
HgSn	15 to 89	0.2980	(35)
HgSn	22 to 99	0.3053	(27)
HgSn <sub>2</sub>	-24 to +15	0.1927	(35)
HgSn <sub>2</sub>	15 to 89	0.2729	(35)
HgSn <sub>2</sub>	21 to 99	0.2758	(27)
HgSn <sub>3</sub>	-23 to +15	0.2009	(35)
HgSn <sub>3</sub>	15 to 89	0.2421	(35)
HgSn <sub>4</sub>	-30 to +15	0.2061	(35)
HgSn <sub>4</sub>	15 to 89	0.2451	(35)
HgSn <sub>5</sub>	-16 to +15	0.2109	(35)
HgSn <sub>5</sub>	15 to 89	0.2319	(35)

**NON-FERROUS ALLOYS****Two-Component****Ag-Al**Ag<sub>3</sub>Al, Mol. wt. = 350.6;  $C_p$ , joule/mole

$t^\circ$	-150	-100	-50	0	+50	(32)
$C_p$	79.84	87.47	93.49	97.74	100.4	
$t^\circ$	200	300	400	500	600	(34)
$C_p$	106.1	109.2	111.6	114.5	116.9	
$t^\circ$	18-100	18-300	18-600	100		(34)
$C_p$	100.2	104.6	108.6	101.8		
$t^\circ$	-182 to +15	15-100	15-227	15-410		(36)
$C_p$	90.99	102.1	103.3	106.5		

Ag<sub>2</sub>Al, Mol. wt. = 242.72;  $C_p$ , joule/mole

$t^{\circ}$ .....	-150	-100	-50	0	+50	(32)				
$C_p$ .....	57.6	64.6	70.1	74.0	76.1					

$t^{\circ}$ .....	18-100	18-300	18-600	100	200	300	400	500	600	(34)
$C_p$ .....	76.2	78.9	82.9	77.5	79.7	81.8	84.9	88.1	92.7	

AgAl<sub>12</sub> (36), Mol. wt. = 431.4

$t^\circ$	-182 to +15	15-100	15-300	15-495
$C_p$	261.3	325.3	343.0	378.0

**Ag-Au** $c_p$ , joule/g (31)

Ag, 80 %	$t^\circ$	-136	-39	+12
Au, 20 %	$c_p$	0.1921	0.2072	0.2147

**Ag-Mg**AgMg, Mol. wt. = 132.2;  $C_p$ , joule/mole

$t^{\circ}$ .....	-150	-100	-50	0	+50	17-100	(32)
$C_p$ .....	36.6	41.4	45.0	47.5	48.9	48.9	

$t^{\circ}$ .....	18-100	18-300	100	200	300	400	500	600	(34)
$C_p$ .....	49.3	51.5	50.4	52.1	53.9	55.6	57.7	59.2	

**Ag-Sb**Ag<sub>3</sub>Sb, Mol. wt. = 445.41;  $C_p$ , joule/mole

$t^\circ$	-150	-100	-50	0	+50	(32)
$C_p$	86.0	94.2	99.9	103.4	103.5	
$t^\circ$	100	200	300	18-100	18-300	(34)
$C_p$	104.4	107.0	117.5	103.3	107.0	



**Ag-Te**Ag<sub>2</sub>Te (36), Mol. wt. = 343.26

$t^\circ$ .....	-182 to +15	15-100	15-180	15-390
$C_p$ .....	74.1	96.6	98.6	95.3

**Al-Bi**Al, 94 %;  $c_m(20-100^\circ) = 0.4367$  (33).**Al-Cu**Al<sub>2</sub>Cu, Mol. wt. = 117.49

$t^\circ$ .....	-150	-100	-50	0	+50	(32)	18-100	18-300	18-600	(34)
$C_p$ .....	48.8	58.7	66.1	71.1	73.7		73.6	61.1	79.2	

AlCu, Mol. wt. = 90.53

$t^\circ$ .....	-150	-100	-50	0	+50	(32)
$C_p$ .....	31.7	38.1	43.0	46.4	48.4	

$t^\circ$ .....	100	200	300	400	18-200	18-400	(34)
$C_p$ .....	49.6	51.7	53.5	56.6	49.6	51.5	

Al<sub>2</sub>Cu<sub>3</sub>, Mol. wt. = 244.63

$t^\circ$ .....	100	200	300	400	500	(34)
$C_p$ .....	92.4	96.0	98.7	100.8	102.3	

AlCu<sub>2</sub>, Mol. wt. = 154.1

$t^\circ$ .....	100	200	300	400	500	(34)
$C_p$ .....	70.5	73.2	75.7	77.7	81.3	

AlCu<sub>3</sub>, Mol. wt. = 217.67

$t^\circ$ .....	-150	-100	-50	0	+50	(32)
$C_p$ .....	68.0	79.8	88.7	94.5	97.5	joule/mole

$t^\circ$ .....	18-100	18-300	18-400	(34)
$C_p$ .....	97.3	101.1	104.8	joule/mole

Al, 11.3 %, soft bronze;  $c_m(20-100^\circ) = 0.437$  (16).Al, 60 %;  $c_m(20-100^\circ) = 0.702$  (33) joule/g.**Al-Mg**Al, 92 %;  $c_p(\text{room}) = 1.15$  joule/g (38).**Al-V**Al, 32.1 %;  $c_m(15-100^\circ) = 0.655$  joule/g (18).**Al-Zn**Al, 60 %;  $c_m(20-100^\circ) = 0.565$  joule/g (33).**As-Sb** $c_p$ , joule/g (30)

$t^\circ$	29.6 % As	16.75 % As	5.56 % As
-190 to -88	0.2176	0.2059	0.1938
-75 to 0	0.2264	0.2264	0.2097
0 to 25	0.2390	0.2331	0.2185

**Au-Cu**Au, 80 %;  $c_p = 0.1636$  at  $-136^\circ$ ,  $= 0.1799$  at  $-39^\circ$ ,  
 $= 0.1829$  at  $+12^\circ$ , joule/g (31).**Au-Mg**

Form.	Mol. wt.	$t^\circ$	-150	-100	-50	0	+50
AuMg	221.52	$C_p$	36.3	41.3	45.1	47.9	49.8
AuMg <sub>2</sub>	245.84	$C_p$	52.1	59.5	65.7	70.3	73.6
AuMg <sub>3</sub>	270.16	$C_p$	65.7	77.2	86.3	93.0	97.1

**Bi-Cd** $c_m(17-100^\circ) = 0.2347 - 0.00108 \times \% \text{ Bi}$ , from 40 to 90 % Bi (14).**Bi-Pb** $c_m(0-100^\circ) = 0.1298 + 0.00013 \times (\% \text{ Bi})$ , from 0 to 50 % (29). $c_m(0-100^\circ) = 0.1471 - 0.00217 \times (\% \text{ Bi})$ , from 50 to 96 %.**Bi-Sn**

Wt. % Bi	99	97	94	90	85
$c_m(0-100^\circ)$	0.1266	0.1315	0.1340	0.1398	0.1433
	joule/g (29)				
Wt. % Bi	50	25	15	7	3
$c_m(0-100^\circ)$	0.1817	0.2088	0.2221	0.2236	0.2266
	joule/g (29)				

Bi, 56.9 %;  $c_m(17-99^\circ) = 0.1883$ ,  $c_m(146-257^\circ, \text{liq.}) = 0.1900$  (25).Bi, 44 %;  $c_m(44-56^\circ) = 0.1759$  (13).**Cd-Sn**Cd, 32.2 %;  $c_m(-77 \text{ to } +20^\circ) = 0.2317$ ;  $(20-100^\circ) = 0.2344$  (35).**Co-Sb**

CoSb, Mol. wt. = 180.74 (32)

$t^\circ$ .....	17-100	-150	-100	-50	0	+50
$C_p$ .....	51.2	38.1	42.7	46.5	49.3	51.1

**Co-Sn**Co<sub>2</sub>Sn, Mol. wt. = 236.64

$t^\circ$ .....	-150	-100	-50	0	+50	17-100	(32)
$C_p$ .....	56.7	64.6	70.9	75.8	79.2	79.4	

$t^\circ$ .....	18-100	18-200	100	200	300	400	500	600	joule/
$C_p$ .....	79.4	84.4	81.9	86.8	89.2	91.7	93.5	95.2	mole (34)

**Cr-Sb**CrSb<sub>2</sub>, Mol. wt. = 295.55;  $C_m(17-100^\circ) = 83.2$  joule/mole (32)

CrSb, Mol. wt. = 173.78 (32)

$t^\circ$ .....	-150	-100	-50	0	+50
$C_p$ .....	35.5	41.5	46.5	50.3	53.1

**Cu-Mg**Cu<sub>2</sub>Mg, Mol. wt. = 151.46

$t^\circ$ .....	-150	-100	-50	0	+50	(32)
$C_p$ .....	45.4	52.2	57.3	60.7	62.4	

$t^\circ$ .....	18-100	18-300	18-500	100	200	300	400	(34)
$C_p$ .....	73.5	76.4	80.5	75.1	78.0	81.3	86.5	

CuMg<sub>2</sub>, Mol. wt. = 112.21 (32)

$t^\circ$ .....	-150	-100	-50	0	+50
$C_p$ .....	49.7	57.7	63.9	68.4	71.2

**Cu-Mn**

Wt. % Cu	$t^\circ$ .....	-136	-39	+12
90	$c_p$ .....	0.323	0.376	0.396
68	$c_p$ .....	0.346	0.400	0.414

**Cu-Ni**

Wt. % Cu	$t^\circ$ .....	-136	-39	+12
95 (31)	$c_p$ .....	0.3059	0.3575	0.3792
90 (31)	$c_p$ .....	0.3072	0.3662	0.3800

Wt. % Cu	$t^\circ$ .....	0	18	100
40 (11)	$c_p$ .....	0.4102	0.4089	0.4269

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**Cu-Sb**Cu<sub>2</sub>Sb, Mol. wt. = 248.91

$t^\circ$ .....	-150	-100	-50	0	+50	(32)
$C_p$ .....	60.6	67.3	72.3	75.6	77.1	

$t^\circ$ .....	100	200	300	18-100	18-300	(34)
$C_p$ .....	79.2	81.7	84.0	77.7	80.5	

Cu<sub>3</sub>Sb, Mol. wt. = 312.48

$t^\circ$ .....	-150	-100	-50	0	+50	17-100	(32)
$C_p$ .....	81.7	90.8	97.6	102.0	104.1	102.5	

$t^\circ$ .....	18-200	18-400	100	200	300	400	(34)
$C_p$ .....	105.0	107.0	106.6	109.5	112.5	116.4	

**Cu-Si**Cu<sub>2</sub>Si, Mol. wt. = 218.77;  $C_m(17-100^\circ) = 97.4$  joule/mole.**Cu-Sn**Cu, 80 %, bell bronze;  $c_m(15-98^\circ) = 0.36$  (28);  $c_m(18-100^\circ) = 0.2279 + 0.0015505 \times \% \text{ Cu}$ , joule/g (from 10 to 90 %) (8).



**Cu-Zn, Brasses**

$c_m(18-100^\circ) = 0.3863 + 0.0000232 \times \% \text{ Zn}$ , joule/g (from 10 to 90 %)(<sup>8</sup>).

Cu, 60%;  $c_m(-186 \text{ to } -79^\circ) = 0.311$  (1, 2);  $(-187 \text{ to } +19^\circ)$ ,  $= 0.414$  (3)  $= 0.339$  (2);  $(20-100^\circ)$ ,  $= 0.384$  (37).

Cu, 60%; with 1.2% Si + 0.44% Pb;  $c_m(-79 \text{ to } +18^\circ) = 0.460$  (2).

**Ir-Pt**

$c_m(20-100^\circ) = 0.1352$  for 10% Ir (26).

**Mg-Ni**

**MgNi<sub>2</sub>**, Mol. wt. = 83.01

$t^\circ$ .....	-79 to +17	17-100	(32)
$C_p$ .....	63.3	74.4	

$t^\circ$ .....	18-100	18-300	18-500	100	200	300	400	500	600	(34)
$C_p$ .....	74.4	74.5	81.9	77.3	81.2	83.6	86.6	87.8	89.4	

**Mg-Si**

**Mg<sub>2</sub>Si**, Mol. wt. = 76.70

$t^\circ$ .....	-150	-100	-50	0	+50	17-100	(32)	100	300	600	(34)
$C_p$ .....	41.4	52.3	60.8	66.7	70.2	70.3		72.2	78.8	84.7	

**Mg-Sb**

**Mg<sub>3</sub>Sb<sub>2</sub>**, Mol. wt. = 316.5

$t^\circ$ .....	-150	-100	-50	0	+50	(32)
$C_p$ .....	90.4	105.6	116.3	123.4	125.9	

**Mg-Zn**

**MgZn<sub>2</sub>**, Mol. wt. = 145.08

$t^\circ$ .....	-150	-100	-50	0	+50	17-100	(32)
$C_p$ .....	57.3	63.9	69.1	72.7	75.0	75.0	

$t^\circ$ .....	18-100	18-300	100	200	300	400	(34)
$C_p$ .....	75.0	78.4	76.6	80.0	83.9	94.1	

**Mn-Ni**

% Mn (31) =	95			90			55		
$t^\circ$ .....	-136	-39	+12	-136	-39	+12	-136	-39	+12
$c_p$ .....	0.387	0.435	0.445	0.386	0.435	0.459	0.386	0.448	0.464

**Ni-Si**

**Ni<sub>2</sub>Si**, Mol. wt. = 145.44

$t^\circ$ .....	-150	-100	-50	0	+50	(32)
$C_p$ .....	42.9	53.6	61.9	67.6	70.7	

$t^\circ$ .....	100	200	300	400	500	600	(34)
$C_p$ .....	72.4	76.1	78.5	80.4	82.5	84.4	

**NiSi**, Mol. wt. = 86.75

$t^\circ$ .....	-150	-100	-50	0	+50	17-100	(32)
$C_p$ .....	25.8	33.5	39.5	43.7	46.3	46.3	

$t^\circ$ .....	300	400	500	600	(34)
$C_p$ .....	52.1	54.0	55.8	57.3	

**Ni-Te**

**NiTe** (36), Mol. wt. = 186.19

$t^\circ$ .....	-182 to +15	15-100	15-180	15-385
$C_p$ .....	44.8	65.7	53.7	54.8

**Pb-Sb**

$c_m(20-100^\circ) = 0.2078 - 0.000790 \times \% \text{ Pb}$  (from 21 to 90 %)(<sup>6</sup>);  $= 0.1301 + 0.000815 \times \% \text{ Sb}$  (from 5 to 96 %)(<sup>15</sup>) joule/g.

**Pb-Sn**

**Pb**, Wt. = 63.7 %

$t^\circ$ .....	-178 to -79	-79 to +18	12-99
$c_m$ .....	0.1507 (2)	0.1628 (2)	0.1705 (28)

**Pb-Tl**

**Pb**, 35%;  $c_m(0-25^\circ) = 0.1281$  (31).

**S-Se**

% S (3).....	4	9	28.8	90.35	90.35
$c_m(0-41^\circ)$ .....	0.3742	0.3906	0.4700	0.6831*	0.7158†

\* S rhombic. † S monoclinic.

**S-Te**

$c_m(0-41^\circ) = 0.3202$  (for 80% S);  $= 0.2913$  for 60% S (23).

**Sb-Zn**

**SbZn** (32), Mol. wt. = 187.15

$t^\circ$ .....	-150	-100	-50	0	+50
$C_p$ .....	40.74	45.91	49.59	51.78	52.49

**Sn-Te**

**SnTe** (36), Mol. wt. = 373.7

$t^\circ$ .....	-182 to +15	15-100	15-180	15-327
$C_m$ .....	73.7	77.1	76.5	77.6

**Sn-Zn**

$c_m(16-100^\circ) = 0.2294 + 0.001636 \times \% \text{ Zn}$  (from 10 to 90 %)(<sup>8</sup>).

**THREE- AND FOUR-COMPONENT ALLOYS**

Heussler alloy, Al, 9; Mn, 17; Cu, 74;  $c_m(0-46^\circ) = 0.4432$ ;  $= 0.4482$  after tempering; for values up to  $320^\circ$ , v. (39)

**d'Arcet's alloys**

% Bi	% Pb	% Sn	$t^\circ$	$c_m$	Lit.
49.2	27.6	21.2	-68 to +20	0.1456	(35)
49.2	27.6	21.2	20 to 86	0.2444	(35)
49	32.5	18.5	12 to 50	0.2051	(25)
49	32.5	18.5	14 to 80	0.2511	(25)
49	32.5	18.5	107 to 136	0.1967*	(25)
49	32.5	18.5	136 to 300	0.1506*	(25)
49.2	32.4	18.4	5 to 65	0.1557	(19)
49.2	32.4	18.4	120 to 150	0.1670*	(19)

**Rose metal**

% Bi	% Pb	% Sn	$t^\circ$	$c_m$	Lit.
48.9	27.5	23.6	-77 to +20	0.1490	(35)
48.9	27.5	23.6	20 to 89	0.2310	(35)
48.9	27.5	23.6	19 to 74	0.2545	(27)
48.7	24	27.6	5 to 65	0.1765	(19)
48.4	24.1	27.5	199 to 338	0.1765*	(25)
32	31.8	36.25	18 to 52	0.1770	(27)
32	31.8	36.25	11 to 98	0.1873	(24)
32	31.8	36.25	143 to 330	0.1925*	(24)

\* Liquid.

**Lipowitz alloy**

Bi, 50.7; Cd, 10.1; Pb, 25.0; Sn, 12.2;  $c_m(5-50^\circ) = 0.1444$ ;  $(100-150^\circ, \text{liq.}) = 0.1783$  (19).

**Wood's metal**

Bi, 52.43; Cd, 6.99; Pb, 25.9; Sn, 14.7;  $c_m(5-50^\circ) = 0.1473$ ;  $(100-150^\circ, \text{liq.}) = 0.1783$  (19).

**Manganin**

Cu, 84; Ni, 4; Mn, 12;  $c_p(0^\circ) = 0.406$ ;  $(18^\circ) = 0.4073$ ;  $(100^\circ) = 0.4202$  joule/g (11).

**Phosphor bronze**

Cu, 88; Sn, 12; P, 0.94;  $c_m(-188 \text{ to } +18^\circ) = 0.3348$  (4);  $(20-100^\circ) = 0.3657$  (37).

**LITERATURE**

(For a key to the periodicals see end of volume)

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(20) Meuthen, *Diss.*, Tech. Hochsch. Aachen, 1912. (21) Nordmeyer and Bernoulli, 96, 9: 175; 07. (22) Oberhoffer, 77, 27: 1764; 07. 192, 4: 447; 07. (23) Padoa, 36, 52 I: 25; 22. (24) Person, 34, 23: 162; 46. 8, 70: 300; 47. (25) Person, 6, 24: 129; 48. 8, 76: 426, 586; 49. (26) Person, 8, 74: 409, 509; 49. (27) Regnault, 6, 1: 129; 41. 8, 53: 243; 41. (28) Regnault, 6, 9: 322; 43. 8, 62: 50; 44. (29) Richter, 8, 42: 779; 14.

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## HEAT CAPACITY OF SOLUTIONS

B. L. VANZETTI

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The values recorded are the true heat capacity at constant pressure,  $c$ , (at  $t^\circ$ ) or the mean heat capacity,  $c_m$  (over  $\Delta t$ ). The unit in all cases is absolute joules per g of solution per  $^\circ\text{C}$ . 1 abs. joule = 0.23895 cal<sub>15</sub> = 0.23918 cal<sub>20</sub> = 0.0009482 BTU<sub>60</sub>. (See further, Vol. I, p. 24.)

Where equations are given,  $p$  = Wt. % of solute. In general, values computed from these equations may be relied upon to ca.  $\pm 0.01$  joule.

## TWO-COMPONENT SYSTEMS

## Aqueous Solutions

## B-TABLE, STANDARD ARRANGEMENT (v. Vol. III, p. viii)

$\text{H}_2\text{O}_2$ , 20–50 $^\circ\text{C}$ (54)		$\text{HBr}$ , 13–96 $^\circ\text{C}$ , with 25%, $c_m$ = 2.99 (58); 16–20 $^\circ\text{C}$ , with 4.3%, $c_m$ = 3.948 (50).		$\text{HNO}_3$ —(Cont'd)	
%	$c_m$	%	$c$	%	$c$
30.59	3.98			90	2.23
34.25	3.68			98	1.99
60.48	3.27				
71.54	3.19			$\text{NH}_4\text{NO}_3$ , 32 $^\circ\text{C}$ (12); cf. (39, 57, 63), $c$ = 4.1787 – 32.051 $\times 10^{-3}p$ – 128.944 $\times 10^{-6}p^2$ – 270.89 $\times 10^{-9}p^3$ , range, 5–70%.	
74.54	(3.28)				
$\text{HF}$ , Room temp. (41, 48)		$\text{HI}$ , 16–20 $^\circ\text{C}$ , with 6.7%, $c_m$ = 3.855 (50).		$\text{NH}_4\text{Cl}$ , 18 $^\circ\text{C}$ (57); cf. (16, 39, 63), $c$ = 4.189 – 43.63 $\times 10^{-3}p$ + 429.9 $\times$ $10^{-6}p^2$ , range, 5–28%.	
%	$c$	%	$c$	%	$c$
5	3.96	8	3.85		
10	3.80	10	3.77		
15	3.65	15	3.60		
20	3.49	20	3.42		
25	3.33	25	3.24		
30	3.17	30	(3.05)		
35	3.02	35	2.84		
$\text{HCl}$ , v. p. 115		40	2.69		
$\text{HClO}_3$ , 18 $^\circ\text{C}$ (24)		$\text{HIO}_3$ , 18 $^\circ\text{C}$ (24)		$\text{NH}_4\text{OH.HCl}$ , 18.7 $^\circ\text{C}$ (15)	
4	4.00	%	$c$	%	$c$
5	3.96	8	3.85	7.2	3.98
10	3.74	10	3.77	1.9	4.085
15	3.52	15	3.60		
20	3.26	20	3.42	$\text{NH}_4\text{Br}$ , 18 $^\circ\text{C}$ (13, 50)	
25	3.00	25	3.24	2.5	4.055
$\text{HClO}_4$ , 13 $^\circ\text{C}$ (3, 49)		30	(3.05)	5	3.95
2.5	4.06	35	2.84	10	3.73
5	3.96	40	2.69	15	3.50
10	3.76			20	3.27
15	3.57			25	3.04
20	3.37			28	2.90
45	(2.24)				
47.5	2.12			$\text{NH}_4\text{I}$ , 18 $^\circ\text{C}$ , $c$ = 3.9 with 3.5%; = 4.03 with 4% (57).	
				$(\text{NH}_4)_2\text{SO}_4$ , 18 $^\circ\text{C}$ (39, 57), $c$ = 4.1605 – 42.58 $\times 10^{-3}p$ + 296 $\times 10^{-6}p^2$ , range, 3.5–33%.	
		20	3.38		
		25	3.22		
		30	3.08		
		40	2.80		
		45	2.77		
		50	2.74		
		60	2.65		
		70	2.55		
		80	2.43		

$(\text{NH}_4\text{OH})_2.\text{H}_2\text{SO}_4$ , 18.6 $^\circ\text{C}$ (15)		$\text{InBr}_3$ , 18 $^\circ\text{C}$ (24)		$\text{CdSO}_4$ , 19 $^\circ\text{C}$ (10, 22), $c$ = 4.167 – 47.49 $\times 10^{-3}p$ + 164.3 $\times 10^{-6}p^2$ , range, 2–45%.	
%	$c$	%	$c$	%	$c_m$
15.4	3.97	5	3.97		
4.36	4.088	10	3.76		
$\text{H}_3\text{PO}_4$ , 0–15 $^\circ\text{C}$ , with 19.04%, $c_m$ = 3.79 (1).		15	3.54		
For C-Compounds, v. p. 124		20	3.32		
		25	3.10		
		30	2.87		
		32	2.78		
		$\text{TlF}$ , 18 $^\circ\text{C}$ (24)		$\text{HgCl}_2$ , 0–98 $^\circ\text{C}$ (7)	
		5	3.94	%	$c$
		10	3.73	1	4.14
		15	3.50	2	4.06
		20	3.28	3	3.97
		25	3.07	18 $^\circ\text{C}$ (24)	
		30	2.87	%	$c$
		$\text{ZnCl}_2$ , 0–50 $^\circ\text{C}$ (7, 39), $c_m$ = 4.185 – 37.61 $\times 10^{-3}p$ + 29.04 $\times 10^{-6}p^2$ , range, 0–65%.		2	4.12
				4	4.05
		$\text{ZnSO}_4$ , 19 $^\circ\text{C}$ (12), $c$ = 4.185 – 51.626 $\times 10^{-3}p$ + 323.6 $\times$ $10^{-6}p^2$ , range, 2.5– 35%.		6	3.99
				$\text{CuCl}_2$ , 19–51 $^\circ\text{C}$ (39)	
		$\text{Zn(NO}_3)_2$ , 20– 50 $^\circ\text{C}$ (39), $c_m$ = 4.185 – 47.09 $\times$ $10^{-3}p$ + 266.6 $\times$ $10^{-6}p^2$ , range, 5– 50%.		%	$c_m$
				3.5	4.00
		$\text{Zn(C}_2\text{H}_3\text{O}_2)_2$ , Ace- tate 19–51 $^\circ\text{C}$ (39)		5	3.94
		%	$c_m$	10	3.73
		5	4.07	15	3.54
		10	3.976	20	3.37
		15	3.87	25	3.20
		20	3.75	30	3.03
		25	3.64	35	2.87
		$\text{CdI}_2$ , 19 $^\circ\text{C}$ (12), $c$ = 4.1816–35.62 $\times$ $10^{-3}p$ – 177.5 $\times$ $10^{-6}p^2$ + 2344 $\times$ $10^{-9}p^3$ , range, 8 –45%.		40	2.70
				42.5	2.62
		$\text{ThCl}_4$ , 18 $^\circ\text{C}$ (24)		$\text{CuSO}_4$ , 18 $^\circ\text{C}$ (39, 42, 57, 60)	
		%	$c$	%	$c$
		5	3.93	2	4.09
		10	3.68	5	3.95
		15	3.43	10	3.73
		20	3.19	15	3.50
		25	2.93	17	(3.41)
		27.2	2.87	$\text{Cu(NO}_3)_2$ , 18–50 $^\circ\text{C}$ (39)	
				%	$c_m$
				5	3.96
				10	3.74
				15	3.54
				17.5	3.44
				$\text{AgNO}_3$ , 25–52 $^\circ\text{C}$ (39)	
				8.5	3.83
				10	3.77
				15	3.59



**AgNO<sub>3</sub>—(Cont'd)**

%	<i>c<sub>m</sub></i>
20	3.41
25	3.22
27.5	3.13

**MnCl<sub>2</sub>, 20–50°C (7, 39)**

3.5	3.98
5	3.91
10	3.70
15	3.52
20	3.34
30	3.03
40	2.76
50	2.51

**MnSO<sub>4</sub>, 20–50°C (39)**

4	3.99
5	3.94
10	3.71
15	3.52

**Mn(NO<sub>3</sub>)<sub>2</sub>, 20–50°C (39)**

5	3.94
10	3.73
15	3.52

**Mn(C<sub>2</sub>H<sub>3</sub>O<sub>2</sub>)<sub>2</sub>, Acetate, 19–52°C (39)**

5	4.03
10	3.896
15	3.766

**FeCl<sub>3</sub>, 0–98°C (7), *c<sub>m</sub>* = 4.274 – 54.72 × 10<sup>-3</sup>*p* + 461.6 × 10<sup>-6</sup>*p*<sup>2</sup>, range, 20–44 %.****FeSO<sub>4</sub>, 25–45°C (1); cf. (57)**

%	<i>c<sub>m</sub></i>
1	4.093
2	4.00
5	3.829
10	3.633
15	3.474
20	3.335
25	3.20
30	3.066
35	2.95

**CoCl<sub>2</sub>, 15–49°C (56)**

8.9	3.62
16.4	3.21
18–90°C	
8.9	3.75
16.4	3.294

**NiCl<sub>2</sub>, 24–55°C (38)**

5	3.87
10	3.61
15	3.38
20	3.17

**NiSO<sub>4</sub>, 26–56°C (38)**

5	3.94
10	3.72
15	3.49

**Ni(NO<sub>3</sub>)<sub>2</sub>, 24–55°C (38)**

%	<i>c<sub>m</sub></i>
5	3.93
10	3.71
15	3.52
20	3.33
25	3.15
28.9	3.00

**Ni(C<sub>2</sub>H<sub>3</sub>O<sub>2</sub>)<sub>2</sub>, Acetate, 26–56°C (39)**

5	4.03
10	3.907
15	3.78

**CrO<sub>3</sub>, 15°C (9, 39), *c* = 4.185 – 0.4612*p* + 0.0002*p*<sup>2</sup>, range, 0–62 %.****(NH<sub>4</sub>)<sub>2</sub>CrO<sub>4</sub>, 21–53°C (39), *c<sub>m</sub>* = 4.174 – 35.12 × 10<sup>-3</sup>*p* + 67.1 × 10<sup>-6</sup>*p*<sup>2</sup>, range, 4–25 %.****AlCl<sub>3</sub>, 18°C (24), *c* = 4.165 – 69.51 × 10<sup>-3</sup>*p* + 321.9 × 10<sup>-6</sup>*p*<sup>2</sup>, range, 2–15 %.****Al<sub>2</sub>(SO<sub>4</sub>)<sub>3</sub>, 21–53°C (39), *c<sub>m</sub>* = 4.187 – 38.13 × 10<sup>-3</sup>*p* + 241.3 × 10<sup>-6</sup>*p*<sup>2</sup>, range, 3–20 %.****Al(NO<sub>3</sub>)<sub>3</sub>, 18°C (24), *c* = 4.181 – 52.71 × 10<sup>-3</sup>*p* + 274 × 10<sup>-6</sup>*p*<sup>2</sup>, range, 3.5–25 %.****AlNH<sub>4</sub>(SO<sub>4</sub>)<sub>2</sub>, 20°C (5), *c* = 4.156 – 38.21 × 10<sup>-3</sup>*p* + 118 × 10<sup>-6</sup>*p*<sup>2</sup>, range, 5–37.5 %.****La(NO<sub>3</sub>)<sub>3</sub>, 18°C (24)**

%	<i>c</i>
5	3.94
10	3.71
15	3.49
20	3.26
25	3.04
30	2.81

**Sa(NO<sub>3</sub>)<sub>3</sub>, 18°C (24)**

5	3.96
10	3.76
15	3.55
20	3.36
25	3.15

**BeCl<sub>2</sub>, 18°C (24)**

2	4.06
5	3.88
10	3.53
14	3.33

**BeSO<sub>4</sub>, 21–52°C (39)**

%	<i>c<sub>m</sub></i>
2.5	4.07
5	3.98
10	3.79
15	3.61
20	3.44

**Be(NO<sub>3</sub>)<sub>2</sub>, 18°C (24)**

%	<i>c</i>
3	4.03
5	3.94
10	3.71
15	3.48
20	3.26

**MgCl<sub>2</sub>, 20–52°C (39); cf. (20) (v. Fig. 1 and Vol. II, p. 328), *c<sub>m</sub>* = 4.185 – 65.7 × 10<sup>-3</sup>*p* + 565 × 10<sup>-6</sup>*p*<sup>2</sup>, range, 5–25 %.****MgBr<sub>2</sub>, 18°C (24)**

%	<i>c</i>
2.5	3.95
5	3.74
10	3.33
15	2.96
17.5	2.78

**MgSO<sub>4</sub>, 18°C (5, 36, 42, 57)**

3	3.99
5	3.90
10	3.67
15	3.46
20	3.28

**Supersaturated solutions**

25	3.11
30	2.94
35	2.75
37.5	2.65

**Mg(NO<sub>3</sub>)<sub>2</sub>, 21–52°C (39), *c<sub>m</sub>* = 4.173 – 46.29 × 10<sup>-3</sup>*p* + 237.8 × 10<sup>-6</sup>*p*<sup>2</sup>, range, 5–35 %.****Mg(C<sub>2</sub>H<sub>3</sub>O<sub>2</sub>)<sub>2</sub>, Acetate, 21–52°C (39)**

%	<i>c<sub>m</sub></i>
5	4.03
10	3.89
14	3.78

**CaCl<sub>2</sub>, 18°C, *c* = 15.401 – 17.016*d* + 5.608*d*<sup>2</sup> between *d*<sub>4</sub><sup>18</sup> = 1.09 and 1.41 (59); cf. (14), *c<sub>m</sub>* = 17.297 – 19.92*d* + 6.696*d*<sup>2</sup> – 0.00263 (20° – *t*), for *d*<sub>4</sub><sup>20</sup> = 1.175 to 1.250 and for any****CaCl<sub>2</sub>—(Cont'd)**  
value of *t* between –25 and 20°C (11).  
See further Fig. 2 and also Vol. II, p. 328.**CaS<sub>2</sub>O<sub>8</sub>, Room temp. (4), *c* = 4.147 – 44.9 × 10<sup>-3</sup>*p*, range, 3–25 %.****Ca(NO<sub>3</sub>)<sub>2</sub>, 21–51°C (39), *c<sub>m</sub>* = 4.163 – 42.61 × 10<sup>-3</sup>*p* + 213.8 × 10<sup>-6</sup>*p*<sup>2</sup>, range, 5–47.5 %.****Ca(C<sub>2</sub>H<sub>3</sub>O<sub>2</sub>)<sub>2</sub>, Acetate, 20–52°C (39)**

%	<i>c<sub>m</sub></i>
5	4.02
10	3.875
15	3.74

**SrCl<sub>2</sub>, 19–51°C (39)**

%	<i>c<sub>m</sub></i>
4	3.95
5	3.90
10	3.65
15	3.42

**Sr(NO<sub>3</sub>)<sub>2</sub>, 19–51°C (39)**

5	3.96
10	3.75
15	3.56
20	3.38

**Sr(C<sub>2</sub>H<sub>3</sub>O<sub>2</sub>)<sub>2</sub>, Acetate, 20–52°C (39)**

5	3.996
10	3.83
15	3.67
18.6	3.56

**LiOH, 20°C (49)**

%	<i>c</i>
0.5	4.17
1.0	4.12
2.5	4.06
5.0	3.99

**LiCl, 18°C (24, 32, 45, 49)**

0.5	4.15
2.5	4.04
5.0	3.92
10	3.68
15	(3.48)
20	(3.30)
25	(3.13)
30	2.98
35	2.83
40	2.69

**LiClO<sub>3</sub>, 18°C (24)**

5.0	3.98
10	3.78
15	3.58
20	3.36
25	3.14

**LiBr, 18°C (24)**

5.0	3.94
10	3.71
15	3.47
20	3.22
25	2.97

**LiI, 18°C (24)**

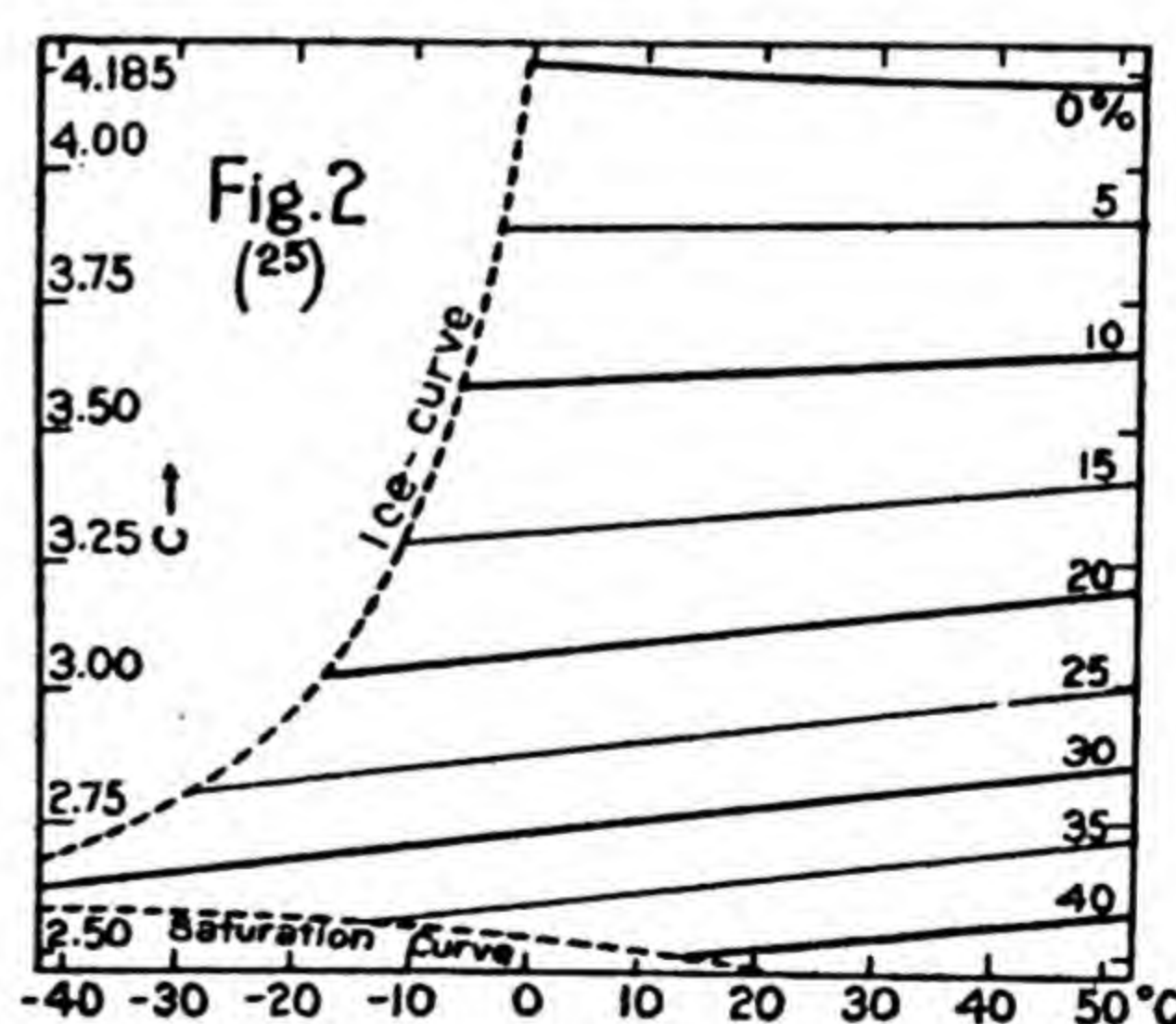
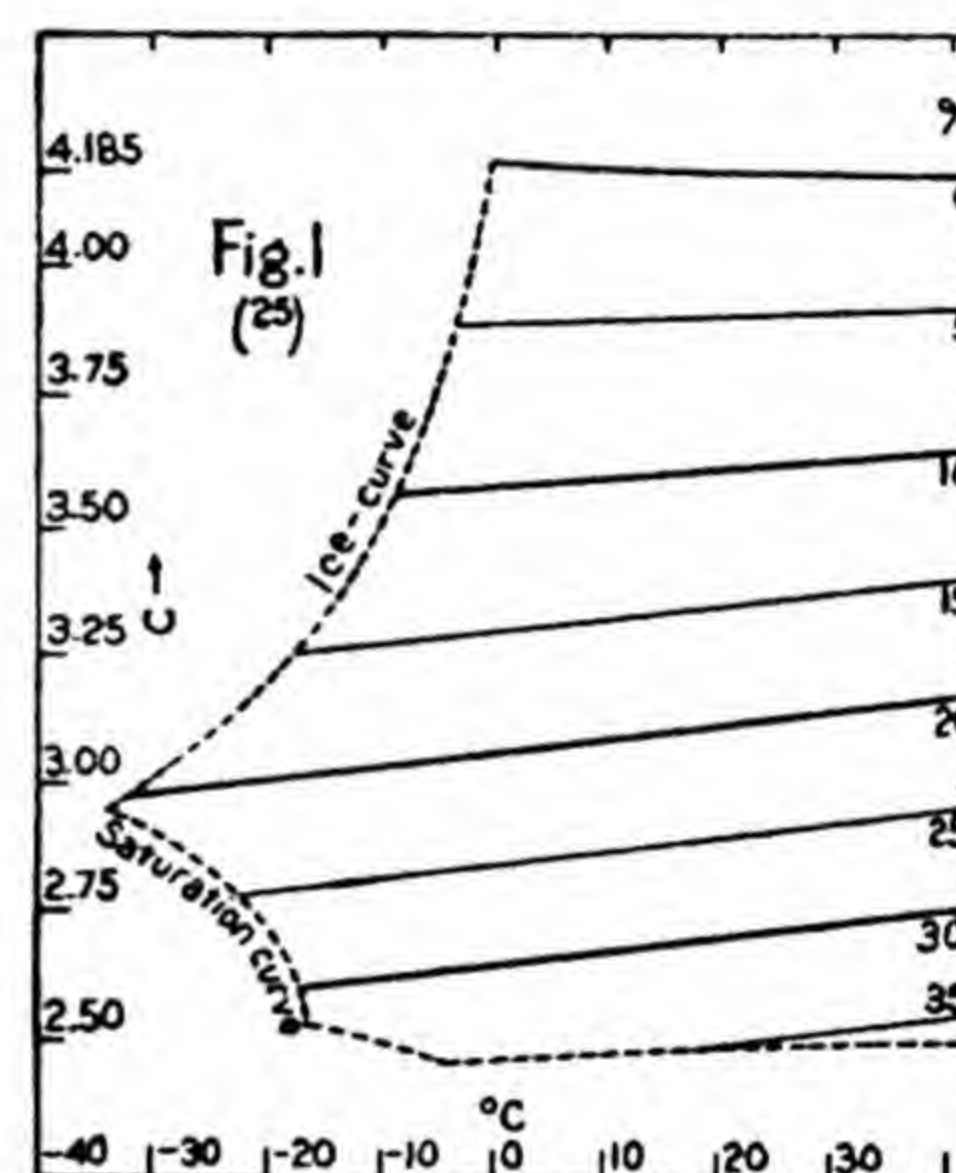
5.0	3.96
10	3.73
15	3.49
20	3.26
25	3.02
30	2.77

**LiO<sub>2</sub>, 18°C (24)**

8.0	3.85
10	3.78
15	3.59
20	3.41
25	3.22
30	3.04
35	2.86

**LiNO<sub>3</sub>, 20°C (49)**

1.0	4.15
5.0	4.01
10	3.82
13	3.70

**NaOH, v. p. 115****NaCl, v. p. 115****NaBr, 18°C (16, 24, 39), *c* = 4.155 – 45.34 × 10<sup>-3</sup>*p* + 135.9 × 10<sup>-6</sup>*p*<sup>2</sup>, range, 5–35 %.****NaI, 18°C (16, 24, 39, 57), *c* = 4.180 – 47.55 × 10<sup>-3</sup>*p* + 126.3 × 10<sup>-6</sup>*p*<sup>2</sup>, range, 4–40 %.**



**Na<sub>2</sub>SO<sub>4</sub>, 18°C (39, 56, 57),**  $c = 4.167 - 47.36 \times 10^{-3}p + 675 \times 10^{-6}p^2$ , range, 3-24%.

**NaHSO<sub>4</sub>, 21°C (39)**

%	$c$
3	4.08
5	4.01
10	3.88
15	3.75
20	3.65

**NaNO<sub>3</sub>, 20°C (39, 47, 49, 57),**  $c = 4.175 - 37.42 \times 10^{-3}p + 216.6 \times 10^{-6}p^2$ , range, 1-39%.

**NaPO<sub>3</sub>, 24-55°C (39)**

%	$c_m$
3	4.07
5	4.00
10	3.83
15	3.67
18.5	3.56

**NaH<sub>2</sub>PO<sub>4</sub>, 24-55°C (39)**

%	$c$
3	4.07
5	4.00
10	3.85
15	3.70
20	3.56

**Na<sub>2</sub>HPO<sub>4</sub>, 24-55°C (39)**

%	$c$
3.8	4.02
7.3	3.91

**Na<sub>2</sub>P<sub>2</sub>O<sub>7</sub>, 24-55°C (39)**

%	$c$
3.6	4.04
6.8	3.92

**NaH<sub>2</sub>AsO<sub>4</sub>, 26-57°C (39)**

%	$c$
5	3.99
10	3.82
15	3.66
18.5	3.50
25	3.35

**Na<sub>2</sub>HAsO<sub>4</sub>, 25-56°C (39)**

%	$c$
5	3.97
10	3.79
15	3.64
17.5	3.57

**Na<sub>2</sub>CO<sub>3</sub>, 20°C (39, 57)**

%	$c$
2.5	4.05
5	3.94
10	3.77
15	3.66
20	3.59

**Na<sub>2</sub>CrO<sub>4</sub>, 21-52°C (39),**  $c_m = 4.159 - 43.13 \times 10^{-3}p + 363.5 \times 10^{-6}p^2$ , range, 5-25%.

**NaHCO<sub>2</sub>, Formate, 16°C (18)**

%	$c$
3.6	4.04
7.8	3.90
13.1	3.73

**NaC<sub>2</sub>H<sub>3</sub>O<sub>2</sub>, Acetate, 18-20°C (5, 39, 57)**

%	$c_m$
2	4.12
5	4.02
10	3.88
15	3.76
20	3.65
25	3.54
30	3.44

**KOH, v. p. 115**

**KF, 18°C (24),**  $c = 4.176 - 54.7 \times 10^{-3}p + 380.9 \times 10^{-6}p^2$ , range, 4-20%.

**KCl, v. p. 115**

**KClO<sub>3</sub>, 20°C (5),**  $c = 4.170 - 56.33 \times 10^{-3}p + 396 \times 10^{-6}p^2$ , range, 5-25%.

**KBr, 18°C (16, 39, 57),**  $c = 4.177 - 47.81 \times 10^{-3}p$ , range, 3-30%.

**KI, 18°C (16, 39, 55, 57)**

%	$c$
4	4.00
5	3.95
10	3.71
20	3.23
30	2.75
40	(2.32)
50	(1.9)
60	(1.5)

**K<sub>2</sub>SO<sub>4</sub>, ca. 18°C (39, 55, 57)**

%	$c$
4	4.02
5	3.92
6	3.85
8	3.77

**KNO<sub>3</sub>, 20°C (39, 47, 49, 57, 63),**  $c = 4.172 - 44.3 \times 10^{-3}p + 421.2 \times 10^{-6}p^2$ , range, 2.5-20%.

**K<sub>2</sub>CO<sub>3</sub>, 21-52°C (39),**  $c = 4.179 - 49.23 \times 10^{-3}p + 331.2 \times 10^{-6}p^2$ , range, 5-45%.

**K<sub>2</sub>C<sub>2</sub>O<sub>4</sub>, 21-52°C (39)**

%	$c_m$
5	3.95
10	3.73
15	3.53

**KC<sub>2</sub>H<sub>3</sub>O<sub>2</sub>, Acetate, 20-51°C (39)**

%	$c_m$
5	4.005
10	3.83
15	3.68
20	3.54
25	3.40
30	3.26
35	3.13
40	3.0
45	2.86
50	2.73

**K<sub>2</sub>CrO<sub>4</sub>, 18°C (16, 39),**  $c = 4.172 - 50.52 \times 10^{-3}p + 234.7 \times 10^{-6}p^2$ , range, 5-30%.

**KAl(SO<sub>4</sub>)<sub>2</sub>, 20°C (5),**  $c = 4.205 - 41.42 \times 10^{-3}p + 254.4 \times 10^{-6}p^2$ , range, 6-40%.

**KNa(NO<sub>2</sub>)<sub>2</sub> (47),**  $c = 4.01$  with 4.7%;  $= 3.59$  with 16.7%.

**RbCl (49)**

**RbBr, 18°C (24)**

%	$c$
7.5	3.82
10	3.70
15	3.45
20	3.19
25	2.93

**RbNO<sub>3</sub> (49)**

**CsCl, 20°C (49)**

%	$c$
2	4.08
5	3.94
10	3.70
15	3.47

**CsBr, 18°C (24)**

%	$c$
8	3.71
10	3.61
15	3.31
20	3.00
25	2.68
30	2.40
35	2.15
40	1.94

**CsNO<sub>3</sub>, 20°C (49)**

%	$c$
2.5	4.07
5	3.96
10	3.74
15	3.54

**C-Table, C-Arrangement (v. Vol. III, p. viii)**

$M_A/M_B$  = Moles H<sub>2</sub>O per Mole Solute

**CH<sub>2</sub>O<sub>2</sub>, Formic acid, 16-50°C (18, 33)**

$M_A/M_B$	$c_m$
200	4.15
100	4.12
50	4.06
40	4.02
30	3.97
20	3.90
15	3.84
10	3.73
8	3.66
6	3.54
5	3.46
4	3.38
3	3.28
2	3.02
1.5	2.94
1.0	2.91
0.5	2.80
0	2.24

**CH<sub>4</sub>N<sub>2</sub>O, Urea, 16-20°C (18, 31, 34, 36)**

%	$c_m$
1	4.16
2.5	4.11
5	4.05
7.5	3.98
10	3.90
12	3.85

**CH<sub>3</sub>O, Methyl alcohol, v. p. 116**

**CH<sub>3</sub>NO<sub>2</sub>, Ammonium formate, 8.5°C (18)**

%	$c$
1.7	4.12
3.4	4.06
6.5	3.95

**C<sub>2</sub>HCl<sub>3</sub>O<sub>2</sub>, Trichloroacetic acid, 14°C (18)**

%	$c$
200	4.09
100	4.00
50	3.84

**C<sub>2</sub>H<sub>2</sub>Cl<sub>2</sub>O<sub>2</sub>, Dichloroacetic acid, 18°C (18)**

$M_A/M_B$	$c$
200	4.12
100	4.06

**C<sub>2</sub>H<sub>3</sub>ClO<sub>2</sub>, Chloroacetic acid, 18°C (18)**

%	$c$
200	4.16
100	4.10
50	4.01
25	3.85

**C<sub>2</sub>H<sub>2</sub>O<sub>4</sub>, Oxalic acid, 20-52°C (39)**

$M_A/M_B$	$c_m$
200	4.11
100	4.03
50	3.94

**C<sub>2</sub>H<sub>4</sub>Cl<sub>3</sub>NO<sub>2</sub>, Ammonium trichloroacetate, 12°C (18)**

%	$c$
4.9	4.09
9.3	4.04

**C<sub>2</sub>H<sub>4</sub>Cl<sub>3</sub>NO<sub>2</sub>, Hydroxylamine trichloroacetate, 19°C (15)**

%	$c$
5.18	4.08
9.85	3.99

**C<sub>2</sub>H<sub>3</sub>O<sub>2</sub>, Acetic acid, v. p. 115**

**C<sub>2</sub>H<sub>5</sub>NO, Acetamide, ca. 20°C (34)**

%	$c$
1.6	4.156
3.2	4.13

**C<sub>2</sub>H<sub>5</sub>O, Ethyl alcohol, v. p. 116**

**C<sub>2</sub>H<sub>4</sub>O<sub>2</sub>, Glycol, 20°C (53)**

%	$c$
10	4.15
20	3.96
30	3.75
40	3.58
50	3.38
60	3.185
70	3.01
80	2.82
90	2.63
100	2.356

**C<sub>2</sub>H<sub>7</sub>NO<sub>2</sub>, Ammonium acetate, 17.5°C (18)**

%	$c$
2.1	4.13
4.1	4.08
7.9	3.98
14.6	3.81

**C<sub>2</sub>H<sub>6</sub>O, Acetone, ca. 17°C (51)**

%	$c$
0	4.181
10	4.15
20	4.08
30	3.98
40	3.87
50	3.75
60	3.56
70	3.33
80	3.01
90	2.66
100	2.196

**C<sub>3</sub>H<sub>5</sub>O<sub>2</sub>, Propionic acid, 22-50°C (18, 33)**

$M_A/M_B$	$c_m$
100	4.16
50	4.12
40	4.11
30	4.09
20	4.03
15	4.01
10	3.88
8	3.76
6	3.63
5	3.55
4	3.43
3	3.26
2	3.03
1.5	2.91
1.0	2.82
0.5	2.48
0	2.19

**C<sub>3</sub>H<sub>7</sub>O<sub>2</sub>, Lactic acid, ca. 16°C (18)**

$M_A/M_B$	$c$
200	4.14
100	4.11
50	4.06
25	3.96

**C<sub>3</sub>H<sub>7</sub>O, Propyl alcohol, v. p. 116**

**C<sub>3</sub>H<sub>8</sub>O<sub>2</sub>, Glycerol, ca. 20°C; cf. p. 116 (29, 34, 35, 36)**

%	$c$
1	4.166
5	4.097
10	4.01

**C<sub>4</sub>H<sub>4</sub>O<sub>6</sub>, Tartaric acid, 18°C (57)**

$M_A/M_B$	$c$
200	4.08
100	3.98
50	3.81
25	3.58
10	3.12

**C<sub>4</sub>H<sub>8</sub>O<sub>2</sub>, n-Butyric acid, 23-50°C (33)**

$M_A/M_B$	$c_m$
50	4.17
40	4.06
30	4.00
20	3.92
15	3.81
10	3.64
8	3.54
6	3.41
5	3.32
4	3.21
3	3.06
2	2.86
1.5	2.79



**C<sub>4</sub>H<sub>10</sub>O<sub>2</sub>—(Cont'd)**

M <sub>A</sub> /M <sub>B</sub>	c <sub>m</sub>
1.0	2.65
0.5	2.42
0	2.11

**C<sub>4</sub>H<sub>10</sub>O**, Isobutyl alcohol, 26–29°C, *c<sub>m</sub>* = 4.55 with 7.6 %; 25–28°C, *c<sub>m</sub>* = 4.47 with 5.5 % (44).

**C<sub>4</sub>H<sub>11</sub>ClN**, Tetramethylammonium chloride, 19°C, *c* = 4.07 with 2.94 % (15).

**C<sub>6</sub>H<sub>6</sub>O**, Phenol, 18–98°C (29); *c<sub>m</sub>* = 4.152 with 2.54 %; for data at 70–74°C, *v.* (16.5).

**C<sub>6</sub>H<sub>6</sub>O<sub>2</sub>**, Hydroquinol, ca. 20°C (35)

%	c
1.5	4.158
2.0	4.15

**C<sub>6</sub>H<sub>6</sub>O<sub>2</sub>**, Pyrocatechol, ca. 20°C (35)

%	c
1.5	4.165
2.0	4.16

**C<sub>6</sub>H<sub>6</sub>O<sub>2</sub>**, Resorcinol, ca. 20°C (35)

%	c
1.5	4.158
2.0	4.15

**C<sub>6</sub>H<sub>7</sub>N**, Aniline, *v.* p. 115

**C<sub>6</sub>H<sub>8</sub>O<sub>7</sub>**, Citric acid, 18°C (55)

M <sub>A</sub> /M <sub>B</sub>	c
200	4.03
100	3.90
50	3.72
25	3.45
15	3.19
10	2.98

**C<sub>6</sub>H<sub>11</sub>Cl<sub>2</sub>NO<sub>2</sub>**, Tetramethylammonium trichloroacetate, 19°C, *c* = 4.058 with 6.17 % (15).

**C<sub>6</sub>H<sub>12</sub>O<sub>6</sub>**, Dextrose, ca. 20°C (34, 37, 55)

%	c
5	4.04
10	3.93
15	3.81
20	3.70
25	3.60
30	3.49
35	3.37
40	3.27
45	3.18
50	3.10
55	3.03

**C<sub>6</sub>H<sub>12</sub>O<sub>6</sub>**, Levulose, ca. 20°C (35, 36)

%	c
4.8	4.09
3.2	4.12
2.4	4.135

**C<sub>6</sub>H<sub>14</sub>O<sub>6</sub>**, Dulcitol, ca. 20°C (35), *c* = 4.136 with 2.5 % = 4.147, with 2 %.

**C<sub>6</sub>H<sub>14</sub>O<sub>6</sub>**, Mannitol, ca. 20°C (35)

%	c
1	4.17
5	4.104
10	4.03

**C<sub>8</sub>H<sub>24</sub>N<sub>2</sub>O<sub>4</sub>S**, Tetramethylammonium sulfate, 18°C, *c* = 4.08 with 6.35 % (15).

**C<sub>12</sub>H<sub>22</sub>O<sub>11</sub>**, Lactose, ca. 20°C, *c* = 3.976 with 8.7 %; = 4.04 with 5.96 % (35).

**C<sub>12</sub>H<sub>22</sub>O<sub>11</sub>**, Maltose, ca. 20°C, *c* = 4.04 with 5.96 %; = 4.074 with 4.54 % (35).

**C<sub>12</sub>H<sub>22</sub>O<sub>11</sub>**, Sucrose, ca. 20°C (29, 34, 36, 55); *cf.* (23)

%	c
5	4.04
10	3.89
15	3.77
20	3.64
30	3.39
40	3.14
50	2.94
60	2.83

**C<sub>14</sub>H<sub>10</sub>O<sub>8</sub>**, Digallic acid, ca. 18°C, *c* = 4.10 with 4.28 % (29).

**B = HgCl<sub>2</sub>—**  
(Cont'd)

% B	c
15	2.51
18	2.45

**B = MnCl<sub>2</sub>**

%	c
5	2.76
7.5	2.73
10	2.70
15	2.65
20	2.60
25	2.55

**B = ZnCl<sub>2</sub>**

% B	c
8.5	2.584
10	2.554
15	2.44
20	2.325
25	2.19
30	2.06
35	1.94
40	1.855
45	1.75

**C<sub>5</sub>H<sub>5</sub>N**

Pyridine, 22°C (40)

B = AgNO <sub>3</sub>	
% B	c
1.06	1.600
B = AgCNS	
1.03	1.593
B = HgCl <sub>2</sub>	
1.68	1.637
B = HgI <sub>2</sub>	
2.79	1.583

2. Both Components Organic Compounds *℄*-Table.—

**CCl<sub>4</sub>**

**B = CHCl<sub>3</sub> (62)**

M <sub>B</sub>	M <sub>A</sub>		20°C	30°C	40°C	50°C
1.00	0.00	<i>c</i>	0.9675	0.981	0.997	1.017
0.75	0.25	<i>c</i>	0.920	0.932	0.947	0.9655
0.50	0.50	<i>c</i>	0.886	0.8955	0.908	0.9235
0.25	0.75	<i>c</i>	0.8535	0.860	0.868	0.8795
0.00	1.00	<i>c</i>	0.833	0.8494	0.8535	0.860

**B = C<sub>6</sub>H<sub>6</sub> (62)**

M <sub>B</sub>	M <sub>A</sub>		20°C	30°C	40°C	50°C	60°C
1.00	0.00	<i>c</i>	1.7075	1.737	1.763	1.8165	1.904
0.75	0.25	<i>c</i>	1.3875	1.400	1.421	1.456	1.551
0.50	0.50	<i>c</i>	1.138	1.1585	1.179	1.203	1.239
0.25	0.75	<i>c</i>	0.962	0.971	0.9835	1.004	1.038
0.00	1.00	<i>c</i>	0.833	0.8495	0.8535	0.860	0.889

% A (52)	20°C	35°C	50°C	% A (52)	20°C	35°C	50°C
0	1.7655	1.986	2.2055	60	1.004	1.197	1.398
10	1.630	1.851	2.065	70	0.927	1.102	1.270
20	1.493	1.716	1.925	80	0.858	1.010	1.147
30	1.358	1.580	1.786	90	0.816	0.930	1.034
40	1.222	1.429	1.654	100	0.807	0.878	0.939
50	1.100	1.305	1.527				

**B = C<sub>6</sub>H<sub>7</sub>N**, Aniline, 25°C (21)

% B	0	10	20	30	40	50
<i>c</i>	0.854	0.99	1.12	1.245	1.365	1.48
% B	60	70	80	90	100	
<i>c</i>	1.60	1.72	1.82	1.93	2.026	

**CS<sub>2</sub>**

**B = CHCl<sub>3</sub> (52)**

% A	−30°C	−10°C	+20°C	% A	−30°C	−10°C	+20°C
0	0.9590	0.9698	0.9786	60	0.887	0.918	0.9685
10	0.942	0.956	0.973	70	0.886	0.921	0.971
20	0.926	0.941	0.971	80	0.898	0.927	0.977
30	0.911	0.935	0.9685	90	0.918	0.950	0.988
40	0.900	0.928	0.968	100	0.9728	0.9850	1.0050
50	0.891	0.922	0.967				

**B = CH<sub>3</sub>O**, Methyl alcohol, *v.* p. 116

## Non-Aqueous Solutions

## 1. One Component an Inorganic Compound

**H<sub>2</sub>SO<sub>4</sub>**

**B = HNO<sub>3</sub>**

20°C (45)

% B	c
0	1.402
5	1.428
10	1.440
20	1.490
25	1.515
30	1.548
40	1.5905
50	1.632
60	1.682
70	1.747
75	1.775
80	1.816
90	1.902
95	1.938
100	1.988

**CS<sub>2</sub>**

ca. 20°C (38)

**B = Br**

% B	c
51	0.730

**B = I**

% B	c
14.3	0.916
7.72	0.954

**B = S**

% B	c
29.6	0.958
17.4	0.971
9.53	0.971
4.05	0.984

**B = P**

% B	c
62	0.916
45	0.929
29	0.942
16.9	0.958
9.27	0.960

**C<sub>2</sub>H<sub>6</sub>O**

Ethyl alcohol, 99.3 %

*d*<sub>4</sub><sup>15</sup> = 0.797; *c<sub>m</sub>* = 2.858; 0–98°C (7)

**B = FeCl<sub>3</sub>**

% B	c
5	2.72
7.5	2.67
10	2.624
15	2.54
20	2.45
25	2.35
30	2.26
32.1	2.226

**B = HgCl<sub>2</sub>**

% B	c
3	2.755
5	2.715
7.5	2.66
10	2.605



CS<sub>2</sub>—(Continued)B = C<sub>4</sub>H<sub>10</sub>O, Ethyl ether (52)

% A	-30°C	-10°C	+20°C	% A	-30°C	-10°C	+20°C
0	2.0675	2.1412	2.2538	60	1.348	1.410	1.491
10	1.938	2.014	2.126	70	1.247	1.295	1.369
20	1.810	1.887	1.998	80	1.143	1.180	1.245
30	1.691	1.768	1.850	90	1.055	1.080	1.122
40	1.576	1.650	1.741	100	0.9728	0.9848	1.0056
50	1.455	1.530	1.613				

B = C<sub>10</sub>H<sub>8</sub>, Naphthalene, at ca. 18°C, c = 1.084 with 14.2% B (17)CHCl<sub>3</sub>B = C<sub>3</sub>H<sub>6</sub>O, Acetone (62)

M <sub>A</sub>	M <sub>B</sub>		20°C	30°C	40°C
1.00	0.00	c	0.9677	0.9807	0.9969
0.75	0.25	c	1.172	1.183	1.197
0.50	0.50	c	1.356	1.377	1.404
0.25	0.75	c	1.6856	1.701	1.745
0.00	1.00	c	2.166	2.232	2.369

% B (52)	-40°C	-10°C	+20°C	35°C
0	0.9542	0.9698	0.9786	0.9850
10	1.333	1.270	1.191	1.144
20	1.651	1.506	1.392	1.314
30	1.814	1.674	1.572	1.480
40	1.876	1.781	1.727	1.625
50	1.87	1.848	1.833	1.743
60	1.82	1.896	1.925	1.856
70	1.80	1.942	2.009	1.965
80	1.82	1.992	2.084	2.067
90	1.88	2.042	2.147	2.155
100	1.9878	2.0897	2.1912	2.2265

B = C<sub>4</sub>H<sub>10</sub>O, Ethyl ether (52)

% A	-50°C	-30°C	-10°C	0°C	+20°C
0	1.955	2.067	2.1413	2.1796	2.2538
10	2.138	2.239	2.178	2.18	2.176
20	2.296	2.334	2.206	2.17	2.094
30	2.411	2.379	2.214	2.150	2.010
40	2.475	2.374	2.195	2.099	1.919
50	2.492	2.320	2.138	2.034	1.822
60	2.415	2.221	2.032	1.925	1.705
70	2.231	2.055	1.873	1.766	1.551
80	1.942	1.787	1.628	1.550	1.373
90	1.490	1.404	1.320	1.281	1.178
100	0.9475	0.961	0.9697	0.973	0.9785

B = C<sub>6</sub>H<sub>6</sub>, Benzene (52)

% A	6°C	20°C	55°C	% A	6°C	20°C	55°C
0	1.559	1.765	1.2796	60	1.275	1.375	1.554
10	1.527	1.704	2.158	70	1.202	1.286	1.420
20	1.488	1.642	2.037	80	1.121	1.186	1.278
30	1.442	1.578	1.915	90	1.042	1.084	1.136
40	1.392	1.514	1.793	100	0.974	0.979	0.994
50	1.336	1.447	1.672				

B = C<sub>10</sub>H<sub>8</sub>, Naphthalene, at 18°C, c = 1.033 with 9.6% B (17)CH<sub>2</sub>O<sub>2</sub>

Formic acid

B = C<sub>2</sub>H<sub>4</sub>O<sub>2</sub>, Acetic acid (30)

M <sub>A</sub>	M <sub>B</sub>	Range, °C	c <sub>m</sub>
0.5	0.5	65-18	2.101

CH<sub>4</sub>N<sub>2</sub>O

Urea

B = C<sub>2</sub>H<sub>5</sub>O, Ethyl alcohol, ca. 20°C (34), c = 2.504 with 2.9% A; = 2.507 with 1.7% ACH<sub>3</sub>O

Methyl alcohol

B = C<sub>2</sub>H<sub>5</sub>O, Ethyl alcohol, v. p. 116B = C<sub>3</sub>H<sub>7</sub>O, n-Propyl alcohol (30); v. also p. 116

M <sub>A</sub>	M <sub>B</sub>	Range, °C	c <sub>m</sub>
0.25	0.75	65-17	2.574
0.5	0.5	65-18	2.532
0.75	0.25	64-16	2.526

B = C<sub>6</sub>H<sub>7</sub>N, Aniline, 25°C (21)

% B.....	0	10	20	30	40	50
c.....	2.532	2.53	2.52	2.51	2.49	2.46
% B.....	60	70	80	90	100	
c.....	2.42	2.37	2.28	2.14	2.026	

C<sub>2</sub>Cl<sub>6</sub>B = C<sub>7</sub>H<sub>8</sub>, Toluene (46)

M <sub>B</sub> /M <sub>A</sub>	7.5	10	15	20	40
c <sub>m</sub> , 18-60°	1.52	1.58	1.63	1.66	1.71

C<sub>2</sub>H<sub>4</sub>Cl<sub>2</sub>

Ethylene chloride

B = C<sub>6</sub>H<sub>6</sub>, Benzene (52)

% A	20°C	35°C	50°	% A	20°C	35°C	50°C
0	1.765	1.986	2.206	60	1.457	1.564	1.671
10	1.715	1.92	2.119	70	1.408	1.495	1.588
20	1.667	1.85	2.031	80	1.357	1.426	1.494
30	1.614	1.77	1.940	90	1.307	1.356	1.406
40	1.561	1.71	1.849	100	1.258	1.287	1.316
50	1.508	1.636	1.760				

C<sub>2</sub>H<sub>4</sub>O<sub>2</sub>

Acetic acid

B = C<sub>3</sub>H<sub>5</sub>O<sub>2</sub>, Lactic acid (30)

M <sub>A</sub>	M <sub>B</sub>	Range, °C	c <sub>m</sub>
0.5	0.5	65-14	2.243

B = C<sub>4</sub>H<sub>8</sub>O<sub>2</sub>, Isobutyric acid (30)

0.49	0.51	65-18	2.042
------	------	-------	-------

B = C<sub>3</sub>H<sub>8</sub>O<sub>3</sub>, Glycerol, ca. 20°C (34)

%	5.3	2.75	1.4
c	2.497	2.497	2.500

C<sub>2</sub>H<sub>5</sub>O

Ethyl alcohol

B = C<sub>3</sub>H<sub>7</sub>O, n-Propyl alcohol

A = 99.6%; equimolal mixture (19); v. also p. 116

T, °K	80	90	95	98	110	200	260	270
c	0.985	1.09	1.26	1.66	2.00	1.88	2.15	2.20

B = C<sub>6</sub>H<sub>6</sub>, Benzene, 15°C (61); v. also p. 116

% B.....	0	10	20	30	40	50
c.....	2.424	2.392	2.35	2.32	2.274	2.23
% B.....	60	70	80	90	100	
c.....	2.175	2.108	2.03	1.91	1.70	

B = C<sub>6</sub>H<sub>5</sub>O<sub>2</sub>; A = 90%; ca. 20°C (35)

B	0.8% B	0.6% B
Hydroquinol	2.13	2.18
Pyrocatechol	2.19	2.15
Resorcinol	2.22	2.10

B = C<sub>6</sub>H<sub>7</sub>N, Aniline, v. p. 116



**C<sub>3</sub>H<sub>6</sub>O**

Acetone

**B = C<sub>4</sub>H<sub>10</sub>O, Ethyl ether (52)**

% A	-40°C	-20°C	0°C	+20°C
0	2.0115	2.1044	2.1797	2.2538
10	1.946	2.042	2.139	2.228
20	1.879	1.986	2.099	2.204
30	1.819	1.933	2.05	2.180
40	1.766	1.883	2.01	2.156
50	1.728	1.846	1.977	2.138
60	1.707	1.825	1.956	2.126
70	1.707	1.822	1.946	2.119
80	1.735	1.846	1.961	2.121
90	1.821	1.917	2.02	2.14
100	1.988	2.0560	2.123	2.1912

**B = C<sub>6</sub>H<sub>5</sub>ClO, o-Chlorophenol, 0-20°C (8)**

% B	0	10	20	30	40	50
c <sub>m</sub>	2.0925	2.042	1.978	1.938	1.892	1.856
% B	60	70	80	90	100	
c <sub>m</sub>	1.828	1.795	1.765	1.72	1.678	

**B = C<sub>6</sub>H<sub>6</sub>, Benzene (52)**

% A	10°C	30°C	50°C	% A	10°C	30°C	50°C
0	1.619	1.9120	2.2055	60	1.833	2.013	2.184
10	1.645	1.917	2.197	70	1.884	2.045	2.194
20	1.674	1.928	2.187	80	1.952	2.087	2.203
30	1.705	1.941	2.180	90	2.044	2.143	2.224
40	1.742	1.960	2.176	100	2.157	2.216	2.266
50	1.786	1.984	2.177				

**C<sub>3</sub>H<sub>6</sub>O<sub>2</sub>**

Methyl acetate

**B = C<sub>4</sub>H<sub>8</sub>O<sub>2</sub>, Ethyl acetate (30)**

M <sub>A</sub>	M <sub>B</sub>	Range, °C	c <sub>m</sub>
0.5	0.5	55-16	1.833

**C<sub>3</sub>H<sub>8</sub>O***n*-Propyl alcohol**B = C<sub>6</sub>H<sub>7</sub>N, Aniline (30)**

0.8	0.2	65-23	2.771
0.35	0.65	65-22	2.478

**B = C<sub>6</sub>H<sub>12</sub>O<sub>2</sub>, Isoamyl formate (30)**

0.742	0.258	65-19	1.946
0.3	0.7	65-18	1.976

**C<sub>3</sub>H<sub>8</sub>O<sub>3</sub>**

Glycerol

**B = C<sub>6</sub>H<sub>7</sub>N, Aniline (34); v. also p. 116**

M <sub>B</sub> /M <sub>A</sub>	12.5	25	50	100
c <sub>m</sub> , 14-16°C	2.271	2.225	2.195	2.1825

**C<sub>4</sub>H<sub>5</sub>Cl<sub>3</sub>O<sub>2</sub>**

Ethyl trichloroacetate

**B = C<sub>4</sub>H<sub>8</sub>O<sub>2</sub>, Ethyl acetate (30)**

M <sub>A</sub>	M <sub>B</sub>	Range, °C	c <sub>m</sub>
0.25	0.75	54-17	1.707
0.5	0.5	54-15	1.39
0.75	0.25	54-16	2.176

**C<sub>4</sub>H<sub>8</sub>O<sub>2</sub>**

Ethyl acetate

**B = C<sub>6</sub>H<sub>12</sub>O<sub>2</sub>, Isoamyl formate (30)**

M <sub>A</sub>	M <sub>B</sub>	Range, °C	c <sub>m</sub>
0.5	0.5	65-16	2.197

**B = C<sub>7</sub>H<sub>14</sub>O<sub>2</sub>, Isoamyl acetate (30)**

M <sub>A</sub>	M <sub>B</sub>	Range, °C	c <sub>m</sub>
0.49	0.51	65-17	2.16
<b>B = C<sub>9</sub>H<sub>10</sub>O<sub>2</sub>, Ethyl benzoate (30)</b>			
0.5	0.5	55-17	1.582

**C<sub>4</sub>H<sub>10</sub>O**

Ethyl ether

**B = C<sub>6</sub>H<sub>5</sub>NO<sub>2</sub>, Nitrobenzene, 20°C (21)**

% B	0	10	20	30	40	50
c	2.260	2.173	2.100	2.000	1.940	1.860
% B	60	70	80	90	100	
c	1.770	1.672	1.590	1.512	1.431	

% B (52)	5°C	20°C	35°C	% B (52)	5°C	20°C	35°C
0	2.1977	2.2538	2.3096	60	1.404	1.413	1.476
10	2.024	2.065	2.147	70	1.356	1.361	1.392
20	1.866	1.900	1.987	80	1.352	1.335	1.356
30	1.720	1.747	1.833	90	1.388	1.345	1.362
40	1.593	1.620	1.695	100	1.5248	1.455	1.4075
50	1.487	1.504	1.578				

**B = C<sub>6</sub>H<sub>6</sub>, Benzene (52) v. also p. 116**

% A	0	10	20	30	40	50
c, 6°	1.559	1.772	1.887	1.953	1.999	2.039
c, 20°	1.765	1.901	1.994	2.052	2.101	2.135
% A	60	70	80	90	100	
c, 6°	2.075	2.106	2.140	2.171	2.201	
c, 20°	2.165	2.190	2.214	2.236	2.2536	

**B = C<sub>6</sub>H<sub>7</sub>N, Aniline (21)**

% B	0	10	20	30	40	50
c, 20°	2.260	2.26	2.25	2.23	2.21	2.185
% B	60	70	80	90	100	
c, 20°	2.16	2.12	2.07	2.03	1.975	

**C<sub>5</sub>H<sub>5</sub>N**

Pyridine

**B = C<sub>6</sub>H<sub>5</sub>ClO, o-Chlorophenol (8)**

% B	0	10	20	30	40	50
c, 0-20°	1.653	1.626	1.60	1.58	1.571	1.580
c, 0-100°	1.720	1.712	1.708	1.709	1.717	1.739
% B	60	70	80	90	100	
c, 0-20°	1.634	1.670	1.702	1.71	1.678	
c, 0-100°	1.765	1.775	1.758	1.720	1.657	

**B = C<sub>7</sub>H<sub>8</sub>O, o-Cresol (8)**

% B	0	10	20	30	40	50
c <sub>m</sub> , 0-20°	1.653	1.658	1.673	1.693	1.720	1.755
% B	60	70	80	90	100	
c <sub>m</sub> , 0-20°	1.806	1.870	1.942	2.016	2.088	

**B = C<sub>7</sub>H<sub>8</sub>O, m-Cresol, (8)**

% A	0	10	20	30	40	50
c <sub>m</sub> , 0-20°	1.653	1.656	1.668	1.686	1.707	1.734
% A	60	70	80	90	100	
c <sub>m</sub> , 0-20°	1.766	1.807	1.863	1.920	2.005	

**C<sub>6</sub>H<sub>4</sub>Br<sub>2</sub>***p*-Dibromobenzene**B = C<sub>7</sub>H<sub>8</sub>, Toluene (46)**

M <sub>B</sub> /M <sub>A</sub>	7.5	10	15	20	40
c <sub>m</sub> , 19-60°	1.52	1.57	1.63	1.66	1.7



**C<sub>6</sub>H<sub>5</sub>Br**

Bromobenzene

B = C<sub>6</sub>H<sub>5</sub>Cl, Chlorobenzene (62)

M <sub>B</sub>	M <sub>A</sub>		20°	40°	60°	80°
1.00	0.00	c	1.294	1.3195	1.3637	1.425
0.75	0.25	c	1.1727	1.198	1.243	1.3016
0.50	0.50	c	1.0796	1.109	1.1426	1.1987
0.25	0.75	c	1.020	1.041	1.0734	1.114
0.00	1.00	c	0.9648	0.975	0.996	1.025
M <sub>A</sub>		M <sub>B</sub>	Range, °C		c <sub>m</sub> (30)	
0.20		0.80	65-17		1.302	
0.675		0.325	65-18		1.151	

**C<sub>6</sub>H<sub>5</sub>ClO**

o-Chlorophenol

B = C<sub>6</sub>H<sub>11</sub>N, Dimethylaniline (8)

% A	0	10	20	30	40	50
c <sub>m</sub> , 0-20°	1.7495	1.791	1.825	1.855	1.895	1.940
% A	60	70	80	90	100	
c <sub>m</sub> , 0-20°	1.955	1.930	1.887	1.810	1.678	

B = C<sub>9</sub>H<sub>7</sub>N, Quinoline (8)

% A	0	10	20	30	40	50
c <sub>m</sub> , 0-20°	1.473	1.465	1.473	1.510	1.550	1.600
% A	60	70	80	90	100	
c <sub>m</sub> , 0-20°	1.667	1.702	1.707	1.69	1.678	

**C<sub>6</sub>H<sub>5</sub>I**

Iodobenzene

B = C<sub>6</sub>H<sub>7</sub>N, Aniline (46)

M <sub>B</sub> /M <sub>A</sub>	2.5	5	10	15	20
c <sub>m</sub> , 19-60°	1.504	1.708	1.864	1.93	1.97

**C<sub>6</sub>H<sub>5</sub>NO<sub>2</sub>**

Nitrobenzene

B = C<sub>6</sub>H<sub>6</sub>, Benzene (52)

% A	10°C	30°C	50°C	75°C
0	1.6186	1.9120	2.2055	2.5735
10	1.545	1.816	2.084	2.428
20	1.480	1.720	1.966	2.282
30	1.418	1.628	1.846	2.139
40	1.365	1.553	1.734	2.007
50	1.322	1.481	1.625	1.876
60	1.289	1.413	1.528	1.749
70	1.277	1.373	1.464	1.652
80	1.305	1.352	1.405	1.547
90	1.366	1.357	1.373	1.454
100	1.4990	1.4200	1.3804	1.3920

B = C<sub>6</sub>H<sub>7</sub>N, Aniline (30)

M <sub>A</sub>	M <sub>B</sub>	Range, °C	c <sub>m</sub>
0.75	0.25	65-13	1.53
0.75	0.25	98-15	1.574
0.5	0.5	65-15	1.689
0.5	0.5	98-18	1.607
0.25	0.75	65-15	1.883

B = C<sub>7</sub>H<sub>9</sub>N, Methylaniline (30)

0.43	0.57	65-17	1.695
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B = C<sub>8</sub>H<sub>11</sub>N, Dimethylaniline (30)

0.46	0.54	65-18	1.707
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B = C<sub>8</sub>H<sub>11</sub>N, Ethylaniline (30)

0.49	0.51	65-16	1.699
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B = C<sub>10</sub>H<sub>11</sub>N, Diethylaniline

M <sub>A</sub>	M <sub>B</sub>	Range, °C	c <sub>m</sub>
0.5	0.5	65-19	1.771

**C<sub>6</sub>H<sub>6</sub>**

Benzene

B = C<sub>7</sub>H<sub>8</sub>, Toluene (62)

M <sub>A</sub>	M <sub>B</sub>		20°C	30°C	40°C	50°C	60°C
1.00	0.00	c	1.706	1.722	1.762	1.824	1.915
0.95	0.05	c	1.698	1.719	1.7596	1.8166	1.892
0.875	0.125	c	1.711	1.720	1.756	1.811	1.885
0.75	0.25	c	1.702	1.733	1.766	1.807	1.864
0.50	0.50	c	1.682	1.712	1.744	1.781	1.827
0.25	0.75	c	1.663	1.692	1.724	1.7596	1.801
0.00	1.00	c	1.6407	1.671	1.701	1.735	1.7714

M <sub>A</sub>	M <sub>B</sub>	Range, °C	c <sub>m</sub> (30)
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0.5	0.5	55-15	1.666
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B = C<sub>7</sub>H<sub>8</sub>O, m-Cresol (30)

0.54	0.46	65-18	2.051
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B = C<sub>8</sub>H<sub>10</sub>, m-Xylene (30)

0.5	0.5	55-15	1.576
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**C<sub>7</sub>H<sub>8</sub>**

Toluene

B = C<sub>10</sub>H<sub>7</sub>Br, β-Bromonaphthalene (46)

M <sub>A</sub> /M <sub>B</sub>	1	5	10	20
c <sub>m</sub> , 22-60°	1.29	1.55	1.64	1.70

B = C<sub>10</sub>H<sub>8</sub>, Naphthalene (46)

M <sub>A</sub> /M <sub>B</sub>	5	10	20
c <sub>m</sub> , 20-50°	1.695	1.72	1.736

**C<sub>7</sub>H<sub>8</sub>O**

m-Cresol

B = C<sub>7</sub>H<sub>9</sub>N, o-Toluidine (30)

M <sub>A</sub>	M <sub>B</sub>	Range, °C	c <sub>m</sub>
0.75	0.25	64-14.5	1.783
0.5	0.5	64.5-14	2.051
0.25	0.75	64-15	2.03

B = C<sub>8</sub>H<sub>11</sub>N, Dimethylaniline (30)

0.53	0.47	65-17	1.825
0.5	0.5	54-17	1.887

**C<sub>8</sub>H<sub>10</sub>**

o-Xylene

B = C<sub>8</sub>H<sub>10</sub>, m-Xylene (30)

M <sub>A</sub>	M <sub>B</sub>	Range, °C	c <sub>m</sub>
0.269	0.731	64-19	1.786
0.729	0.271	65-20	1.808

B = C<sub>8</sub>H<sub>10</sub>, p-Xylene

0.815	0.185	65-16	1.754
0.32	0.68	64-20	1.825

**C<sub>8</sub>H<sub>10</sub>**

m-Xylene

B = C<sub>8</sub>H<sub>10</sub>, p-Xylene (30)

M <sub>A</sub>	M <sub>B</sub>	Range, °C	c <sub>m</sub>
0.754	0.246	65-18	1.674
0.293	0.708	65-17	1.724

B = C<sub>8</sub>H<sub>11</sub>N, Dimethylaniline (30)

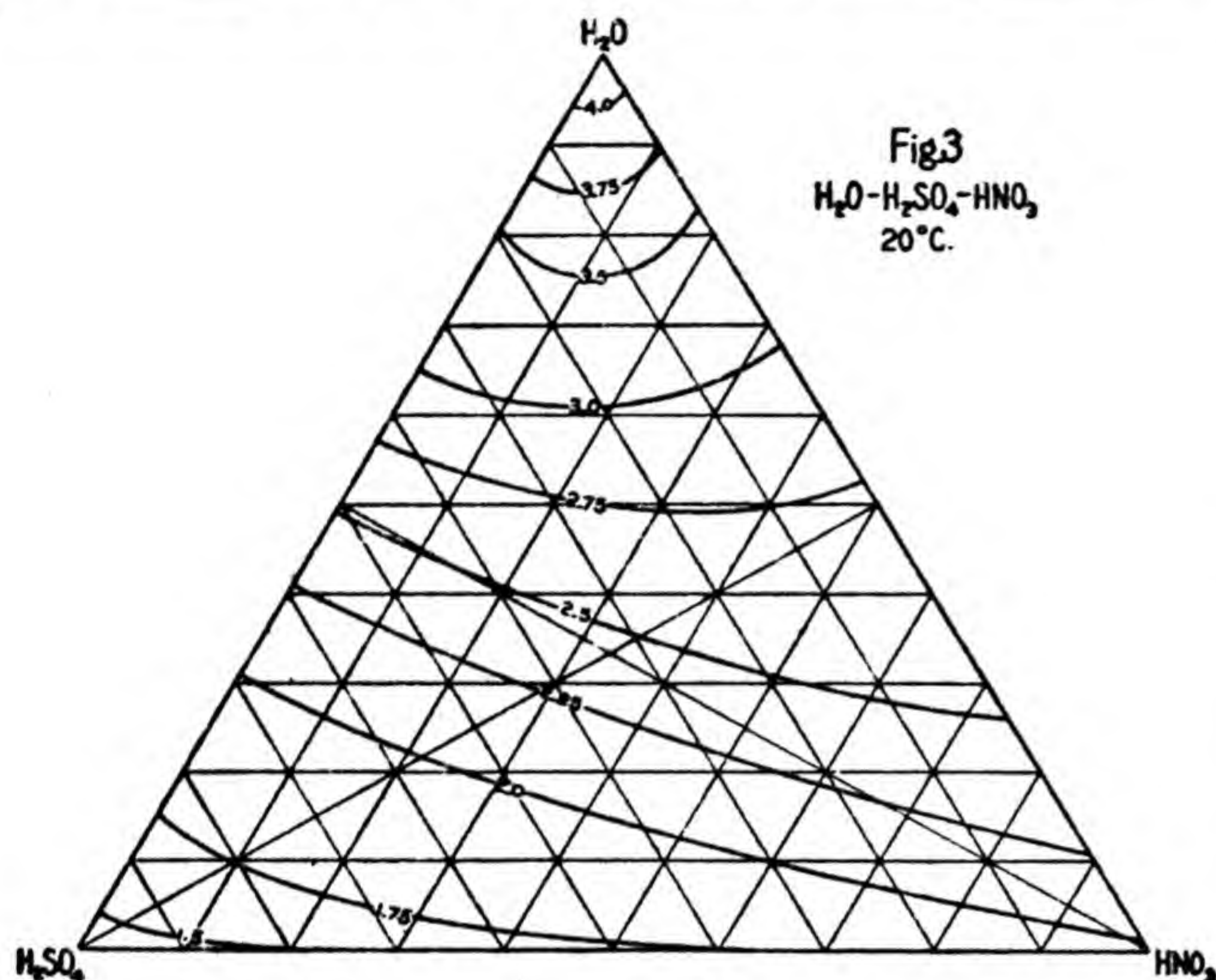
0.734	0.266	65-19	1.707
0.287	0.713	65-18	1.808



## THREE-COMPONENT SYSTEMS

 $\text{H}_2\text{O} + \text{H}_2\text{SO}_4 + \text{HNO}_3$ ,  $t = 20^\circ\text{C}$  (45); v. Fig. 3

% $\text{H}_2\text{O}$	$\text{H}_2\text{SO}_4$	$\text{HNO}_3$	$c$	% $\text{H}_2\text{O}$	$\text{H}_2\text{SO}_4$	$\text{HNO}_3$	$c$
10	45	45	1.887	15	70	15	1.84
20	40	40	2.12	30	10	60	2.55
40	30	30	2.545	50	10	40	2.74
50	25	25	2.745	75	10	15	3.37
60	20	20	2.93	40	40	20	2.45
75	12.5	12.5	3.51	10	80	10	1.76
85	7.5	7.5	3.8	5	5	90	2.00
10	10	80	2.13	2.5	70	27.5	1.67
10	30	60	1.97	5	25	70	1.92
10	50	40	1.88				

Fig. 3  
 $\text{H}_2\text{O}-\text{H}_2\text{SO}_4-\text{HNO}_3$ ,  
 $20^\circ\text{C}$ . $\text{H}_2\text{O} + \text{C}_2\text{H}_5\text{OH} + \text{a salt}$ ,  $t = \text{ca. } 20^\circ\text{C}$ ; v. also p. 116

Salt	Moles $\text{C}_2\text{H}_5\text{OH}$ per 200 moles $\text{H}_2\text{O} + 1$ mole salt							Lit.
	100	50	40	35	30	15	10	
NaCl.....	3.632*	4.072	4.152	4.160†	4.243	4.264‡	4.231	(26)
KCl.....	3.574	3.984	4.126	4.156	4.206	4.236		(27)
$\text{NaNO}_3$ .....	3.616	4.021	4.126	4.160	4.206	4.248		(27)
$\text{KNO}_3$ .....	3.591	4.021	4.122	4.126	4.193	4.649	4.185	(27)
NaBr.....			4.093					(28)
KBr.....			4.072					(28)
NaI.....			4.05					(28)
KI.....			4.024					(28)

\* For  $\text{C}_2\text{H}_5\text{OH} = 200$  moles,  $c = 3.277$ .†  $\text{C}_2\text{H}_5\text{OH} = 33.33$  moles.‡  $\text{C}_2\text{H}_5\text{OH} = 20$  moles. $\text{H}_2\text{O} + \text{C}_2\text{H}_5\text{OH} + x$  (29); 80 moles  $\text{C}_2\text{H}_5\text{OH} + 200$  moles  $\text{H}_2\text{O} + 1$  mole  $x$ ,  $t = \text{ca. } 18^\circ\text{C}$ 

$x$	$\text{C}_2\text{H}_5\text{O}_2$ , Glycerol	$\text{C}_6\text{H}_6\text{O}$ , Phenol	$\text{C}_{12}\text{H}_{22}\text{O}_{11}$ , Sucrose	Tannic acid (Digallic?)
$c$	4.120	4.168	4.1225	(4.10)

 $\text{H}_2\text{O} + \text{C}_{12}\text{H}_{22}\text{O}_{11} + \text{NaCl}$ ,  $t = 21.4^\circ\text{C}$  (4)

$\text{H}_2\text{O}$ , moles	NaCl		$\text{C}_{12}\text{H}_{22}\text{O}_{11}$		$c$
	Moles	%	Moles	%	
200	1	1.59	0	0	4.0865
	0.75	1.17	0.25	2.29	4.054
	0.5	0.768	0.5	4.498	4.027
	0.25	0.378	0.75	6.62	3.991
	0	0	1	8.67	3.969
100	1	3.14	0	0	4.008
	0.75	2.29	0.25	4.47	3.957
	0.5	1.46	0.5	8.55	3.908
	0.25	0.702	0.75	12.38	3.854
	0	0	1	15.95	3.796
50	1	6.09	0	0	3.8825
	0.75	4.26	0.25	8.30	3.778
	0.5	2.66	0.5	15.53	3.685
	0.25	1.26	0.75	21.23	3.605
	0	0	1	27.55	3.522
25	1	11.48	0	0	3.678
	0.75	7.56	0.25	14.76	3.500
	0.5	4.49	0.5	26.30	3.364
	0.25	2.05	0.75	36.06	3.260
	0	0	1	43.23	3.163

## LITERATURE

(For a key to the periodicals see end of volume)

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## LATENT HEATS OF FUSION

R. DE FORCRAND AND L. GAY

**Scope of the Tables.**—The data given in the following tables are based solely upon the best available direct calorimetric determinations and do not take into account the values, sometimes more reliable, which can be computed by indirect methods. For such values the reader should consult the appropriate sections of I. C. T. as indicated in the index under, "Fusion, heat of."

**Calorimetric Methods.** A.— $m$  grams of the pure substance which has been in the crystalline state for a long period of time (hereafter referred to as the "stable" crystalline form) is taken at a temperature slightly below its fusion point  $t_f$  and is introduced into a calorimeter, the temperature of which is slightly above  $t_f$ . The final state of the substance is liquid. The total effect produced is composed of (a) the heat absorbed by the solid up to  $t_f$ , (b) the heat absorbed by the liquid between  $t_f$  and the final temperature, and (c) the heat of fusion. Knowing the two specific heats, the heat of fusion,  $L_f$ , at the M. P., is obtained by difference.

B.—As in Method A, but in the reverse order, the liquid substance slightly above its fusion point is introduced into the calorim-

eter, where it crystallizes. This experiment gives directly the heat of solidification,  $L_D$ , rather than the heat of fusion,  $L_f$ . The heat of solidification is sometimes less than the heat of fusion, because at the moment of solidification the substance does not always liberate its entire heat of fusion. The determination of  $L_f$  is therefore preferable.

C.—Two samples of the pure substance are employed, one in the "stable" crystalline form, the other in the form of the supercooled liquid, and both at the same temperature, which is substantially that of the calorimeter. In two separate experiments the substance is brought to the same final state which may be anything, but is the same for the two samples. The difference between the two values found gives directly the heat of fusion. In this case there is no difference between  $L_f$  and  $L_D$  if the crystalline sample employed is in the "stable" form. In most cases the final state in such an experiment is a solution in the calorimetric liquid, but obviously it might be any state. The value finally obtained by Method C is the heat of fusion at the temperature of



the calorimeter and is identical with the heat of fusion at the melting point only in case the calorimeter is operated in the neighborhood of this temperature.

D.—The super-cooled substance is maintained in the calorimeter until temperature equilibrium is secured, and crystallization is then produced by seeding. This method gives  $L_D$ .

E.—In this method (Wigand) the "stable" crystalline substance is melted in the calorimeter by means of a measured amount of electrical energy. This method gives  $L_F$  directly, but requires a calorimetric liquid with a melting point lower than  $t_F$ .

F.—The method of thermo-analysis (W. Plato) gives reliable results in cases where  $L_F$  is known for an analogous substance having approximately the same melting point. The method is a relative one.

G.—In the method of L. Meyer, a Bunsen calorimeter is employed, the calorimetric liquid being the pure substance at its melting point. The determination consists in measuring the variation in volume,  $\Delta V$ , which accompanies the fusion of 1 g of the substance. In a second experiment, a known quantity of heat  $Q$  is introduced into the calorimeter electrically and the accompanying volume change  $\Delta V'$  is measured.  $\Delta V'/\Delta V$  gives the mass  $m$  of the substance melted. The heat of fusion is then

$$\frac{Q}{m} = \frac{Q}{\Delta V'} \Delta V.$$

The temperature  $t_F$  being constant, a knowledge of the specific heats is unnecessary.

H.—Special methods, for which see the literature cited.

I.—Method not given by the author.

Conversion Factors.—1 Kilojoule per g = 238.9 cal<sub>15</sub> g<sup>-1</sup> = 430.1 BTU<sub>40</sub> lb.<sup>-1</sup> = 9.869 l-atm. g<sup>-1</sup> = 2.778 × 10<sup>-4</sup> kw hr g<sup>-1</sup>. For other factors, v. Vol. I, p. 24.

#### NON-METALLIC ELEMENTARY SUBSTANCES\*

Formula	M. P., °C	Joule per g	Kilojoule per g-atom	Method	Lit.
A	-190	28.1	1.12	A	(18)
O	-219	13.8	0.221	A	(18)
H		63 ± 6	0.063	E	(42)
		58.6 ± 0.3	0.0591	A	(70)
Cl	-103.5	96.1	3.408	A, E	(17, 18.5)
Br	-7.32	67.7 ± 0.7	5.410	A	(62)
S	115	39.215	1.257	B	(54)
	118.95	43.6 ± 1.2	1.40	E	(84)
	119	55.2	1.77	B	(40)
		37.05	1.188	E	(74)
Te	446				(90)
N	-210	25.5	0.36	A	(18)
P	44.2	21.07	0.6538	B	(54)

\* For heats of fusion of metallic elementary substances, v. Vol. II, p. 458.

#### B-TABLE.—CHEMICAL COMPOUNDS (STANDARD ARRANGEMENT) (v. Vol. III, p. viii)

Formula	M. P., °C	Joule per g	Kilojoule per g-formula-wt.	Method	Lit.
H <sub>2</sub> O	0	333.6 ± 0.33	6.0099	E	(14.1)
H <sub>2</sub> O <sub>2</sub>	-1.7	310 ± 1.25	10.5 ± 0.04	A	(47)
HBr	-86	32.1	2.60	E	(18.5)
	-86.8	29.7	2.41	E	(87)
HCl	-114	58	2.11	E	(18.5)
	-114	54.6	1.99	E	(86)
HCl·2H <sub>2</sub> O	-18.5	144.68	10.488	C	(8)
HI	-53	23.76	3.04	E	(18.5)
ICl(α)	27.2	68.75 ± 1.0	11.16 ± 0.16	A	(73)
ICl(β)	15.2 ± 1.3	58.6 ± 0.65	9.52 ± 0.1	C, A	(6, 73)
SO <sub>2</sub>	-30	99.4	7.96	C	(30)
H <sub>2</sub> SO <sub>4</sub>	10.352	100.6 ± 0.7	9.865 ± 0.07	A	(87)

#### B-TABLE.—(Continued)

Formula	M. P., °C	Joule per g	Kilojoule per g-formula-wt.	Method	Lit.
H <sub>2</sub> SO <sub>4</sub> —(Cont'd)	10.49	95.5	9.36	A	(43)
	8.56*	108.76	10.668	A	(11)
H <sub>2</sub> SO <sub>4</sub> ·H <sub>2</sub> O		163.6 ± 3.0	19 ± 0.35	A	(11, 46, 87)
H <sub>2</sub> S <sub>2</sub> O <sub>7</sub>	35	75.0 ± 4	1.35	D	(1.5)
NO	-163	77	2.32	E	(18.5)
N <sub>2</sub> O <sub>4</sub>	-10.14	135 to 155.5	12.4 to 14.35	A	(61)
N <sub>2</sub> O <sub>5</sub>	29.57	320.95?	34.665?	I	(3)
NH <sub>3</sub>	-75	452.5	7.7	A	(40)
	-77.6	351	5.98	E	(18.5)
HNO <sub>3</sub>	-47	39.95	2.518	C	(3)
H <sub>3</sub> PO <sub>4</sub>	17.4	146.5	9.68	C	(78)
POCl <sub>3</sub>	2	83	12.7	A	(81)
AsBr <sub>3</sub>	31	37.4	11.75	B	(79)
SbCl <sub>3</sub>	73.2	55.68	12.69	B	(79)
SbBr <sub>3</sub>	94	40.88	14.77	B	(79)
Sb <sub>2</sub> S <sub>3</sub>	540	73.5	24.9	B	(35, 41)
CO	-206	33.5	0.094	A	(18)
CO <sub>2</sub>	-56.2	189.6	8.35	A	(47.5)
For other C-compounds, v. C-Table					
SiCl <sub>4</sub>	70.3	45.42	7.78	E	(44)
TiCl <sub>4</sub>	-25	49.27	9.348	E	(44)
SnCl <sub>4</sub>	-33	35.16 ± 0.8	9.160	E	(44)
SnBr <sub>4</sub>	25.5	26.2 ± 0.1	11.5	B, C	(5, 79)
PbCl <sub>2</sub>	485	87.5 ± 1.8	24.3	B	(16)
				F	(58)
	498	77.5	21.5	B	(31)
PbBr <sub>2</sub>	490	51.65 ± 1.5	18.96 ± 0.55	B	(16)
	488	41.5	15.2	B	(31)
PbI <sub>2</sub>	375	48.1 ± 1.2	22.2 ± 0.55	B	(16)
TiCl <sub>3</sub>	427	69.5	16.7	B	(31)
TiBr <sub>3</sub>	460	53	15.1	B	(31)
TiOC <sub>2</sub> H <sub>5</sub>		4.4	1.1	C	(26.5)
Zn(NO <sub>3</sub> ) <sub>2</sub> ·6H <sub>2</sub> O	36.4	130	38.6	B	(62)
Cd(NO <sub>3</sub> ) <sub>2</sub> ·4H <sub>2</sub> O	59.5	106	32.7	B	(62)
HgBr <sub>2</sub>	235	53.6	19.32	B	(34)
HgI <sub>2</sub>	250	41	18.6	H	(33)
Cu(NO <sub>3</sub> ) <sub>2</sub> ·6H <sub>2</sub> O	24.4	123	36.4	B	(63)
AgCl	451	128.5	18.4	B	(64)
	455	89	12.8	B	(31)
AgBr	430	52.5	9.9	B	(31)
AgNO <sub>3</sub> cf. (89)	208	74.25 ± 0.75	12.6 ± 0.1	H	(33)
	218	63.5	10.8	B	(31)
OsO <sub>4</sub>	40.1	56.6 ± 1	14.4 ± 0.2	G	(81.5)
Mn(NO <sub>3</sub> ) <sub>2</sub> ·6H <sub>2</sub> O	25.8	120.5	34.6	B	(63)
Co(NO <sub>3</sub> ) <sub>2</sub> ·6H <sub>2</sub> O		126.5	36.8	B	(63)
Ni(NO <sub>3</sub> ) <sub>2</sub> ·6H <sub>2</sub> O	56.7	152.5	44.3	B	(63)
MgCl <sub>2</sub> ·6H <sub>2</sub> O	116.7	172.5	35.1	B	(63)
Mg(NO <sub>3</sub> ) <sub>2</sub> ·6H <sub>2</sub> O	90	160	41	B	(63)
CaCl <sub>2</sub>	773.9	227.15 ± 1.35	25.21 ± 0.14	F	(58, 67)
CaCl <sub>2</sub> ·6H <sub>2</sub> O	29 ± 0.5	170.5	37.3	B	(65)
Ca(NO <sub>3</sub> ) <sub>2</sub> ·4H <sub>2</sub> O	42.1 ± 0.1	142.2 ± 2.2	33.6 ± 0.5	A	(67)
				I	(76)
SrCl <sub>2</sub>	872.3	106.5 ± 0.5	16.85 ± 0.05	F	(58)
BaCl <sub>2</sub>	958.9	115	24	F	(58)
LiNO <sub>3</sub>	250	370.5	25.58	B	(31)
Li <sub>2</sub> SiO <sub>3</sub>		335.5	30.2	F	(68)
Li <sub>2</sub> SiO <sub>3</sub> ·Li <sub>2</sub> O		260	31.1	F	(68)
NaOH	318.4	167.5	6.7	F	(37)
NaF	992.2	779	32.71	F	(58.1)
NaCl	804.3	517	30.2	F	(58)
NaClO <sub>3</sub>	255	205.0 ± 2.5	21.825 ± 0.27	B	(33, 31)
Na <sub>2</sub> SO <sub>4</sub> ·10H <sub>2</sub> O	31	214.5	69	B	(12)
	31.5	239	77.0	B	(48)
Na <sub>2</sub> S <sub>2</sub> O <sub>5</sub> ·5H <sub>2</sub> O		200.0 ± 0.5	49.65 ± 0.15	B	(48)
NaNO <sub>2</sub>	333	189.5	16.1	B	(31)
Na <sub>2</sub> HPO <sub>4</sub> ·12H <sub>2</sub> O	36.1	279.5	100.1	B	(58)
Na <sub>2</sub> CrO <sub>4</sub> ·10H <sub>2</sub> O	23 to 30	164.0 to 150.8	56.12 to 51.59	C	(5)
KOH	360.4	119.5	6.72	F	(37)
KF	859.9	452	26.3	F	(58.1)
KCl	772.3	310 ± 50	23.1 ± 3.7	F	(58)
KNO <sub>3</sub>	308	106.5	10.8	B	(31)
K <sub>2</sub> Cr <sub>2</sub> O <sub>7</sub>	397	124.5	36.7	B	(31)
RbOH	301	66	6.75	F	(37)
RbCl		159	19.2	F	(58)
CaOH	272.3	45	6.7	F	(37)

\* ± 0.06.



C-TABLE  
The C-Arrangement (v. Vol. III, p. viii)

Formula	Name	M. P., °C	Joule per g	Kilojoule per g-formula-wt.	Method	Lit.
CCl <sub>4</sub>	Carbon tetrachloride	-24	17.4 ± 0.25	2.68	E	(44)
CH <sub>2</sub> N <sub>2</sub>	Cyanamide	42.9	208.5 ± 3	11.27	B	(60)
CH <sub>2</sub> O <sub>2</sub>	Formic acid	8.0 ± 0.6	246.5 ± 1.9	11.34	A, B	(32, 56)
CH <sub>4</sub>	Methane	-182.6	60.8	0.974	E	(18.5)
CH <sub>4</sub> O	Methyl alcohol	-97	68.6	2.20	A	(48)
		-97.8	92.2	2.95	E	(53.5)
C <sub>2</sub> HCl <sub>3</sub> O <sub>2</sub>	Trichloroacetic acid	59.1	36	5.9	B	(57)
C <sub>2</sub> H <sub>2</sub> Cl <sub>2</sub> O <sub>2</sub>	Dichloroacetic acid	10.8	59.5	7.65	B	(57)
C <sub>2</sub> H <sub>3</sub> Br <sub>3</sub> O <sub>2</sub>	Bromal hydrate	46	70.75	21.15	B	(10)
C <sub>2</sub> H <sub>3</sub> ClO <sub>2</sub>	Chloroacetic acid (α)	61.2	130	12.3	B	(57)
	Chloroacetic acid (β)	56	147	13.8	B	(57)
C <sub>2</sub> H <sub>3</sub> Cl <sub>3</sub> O <sub>2</sub>	Chloral hydrate		138.9	22.97	C	(4)
C <sub>2</sub> H <sub>4</sub> Br <sub>2</sub>	Ethylene dibromide	9.55	56.62	10.637	B	(14)
C <sub>2</sub> H <sub>4</sub> O <sub>2</sub>	Acetic acid	16.58 ± 0.04	187.1 ± 6.7	11.23	B*	(46, 56)
		16.7	181	10.9	E	(53.7)
C <sub>2</sub> H <sub>6</sub> O	Ethyl alcohol	-114.4	104.2 ± 3.7	4.80	A, E	(29, 53.5)
C <sub>2</sub> H <sub>6</sub> O <sub>2</sub>	Glycol	-11.5	181.1	11.24	A	(24)
		-12.3	174	10.8	E	(53.5)
C <sub>3</sub> H <sub>4</sub> O <sub>2</sub>	Acrylic acid	13	155	11.2	I	(66)
C <sub>3</sub> H <sub>5</sub> N <sub>3</sub> O <sub>3</sub>	Trinitroglycerol	12.3	96.35	21.88	B	(52)
	Stable form		21.8†	4.95†	D	(38)
	Metastable form	13	138.9†	31.5†	D	(38)
C <sub>3</sub> H <sub>6</sub> O	Acetone	-95.5	98	5.69	E	(53.7)
		-94.6	82	4.76	B	(48)
C <sub>3</sub> H <sub>7</sub> NO <sub>2</sub>	Urethane	48.7	171	15.2	B	(19)
C <sub>3</sub> H <sub>8</sub> O	Isopropyl alcohol	-88.5	88	5.34	E	(53.7)
C <sub>3</sub> H <sub>8</sub> O <sub>2</sub>	Glycerol	18	198.8	18.3	B	(28)
C <sub>4</sub> H <sub>4</sub> N <sub>2</sub>	Succinonitrile	54.5	49	3.92	I	(76)
C <sub>4</sub> H <sub>4</sub> O <sub>3</sub>	Succinic anhydride	119	204	20.4	I	(76)
C <sub>4</sub> H <sub>6</sub> O <sub>2</sub>	Crotonic acid (α)	67.4	106.0	9.11	B	(10)
	Crotonic acid (α)	71.4	152.4 ± 4	13.1	B	(46.5)
	Crotonic acid (cis)	71.23	146.15	12.575	B	(9.1)
C <sub>4</sub> H <sub>6</sub> O <sub>4</sub>	Methyl oxalate	49.5	178.5	21.05	B	(10)
C <sub>4</sub> H <sub>7</sub> Cl <sub>3</sub> O <sub>2</sub>	Chloral alcoholate	9	100.6	19.455	C	(7)
C <sub>4</sub> H <sub>8</sub> N <sub>2</sub> S	Thiosinamine	77	140	16.25	B	(89)
C <sub>4</sub> H <sub>8</sub> O <sub>2</sub>	n-Butyric acid	-5.7	126	11.1	E	(53.6)
C <sub>4</sub> H <sub>10</sub> O	n-Butyl alcohol	89.2	125.3 ± 0.2	9.280	E	(53.5)
	tert.-Butyl alcohol	25.45	87.8	6.505	C	(25)
	tert.-Butyl alcohol	25.4	91.6	6.78	E	(53.6)
C <sub>4</sub> H <sub>8</sub> O <sub>3</sub>	Levulinic acid	33	79.4	9.215	C	(8)
C <sub>4</sub> H <sub>8</sub> O <sub>4</sub>	Glutaric acid	99.3	156.5	20.65	B	(36)
C <sub>5</sub> H <sub>12</sub> O	tert.-Amyl alcohol		52.5	4.65	I	(76)
C <sub>5</sub> H <sub>3</sub> Br <sub>3</sub> O	2, 4, 6-Tribromophenol	93	56	18.55	B	(89)
C <sub>5</sub> H <sub>4</sub> BrCl	o-Bromochlorobenzene	-12.6	64.5	12.35	I	(51)
	m-Bromochlorobenzene	-21.2	64	12.25	I	(51)
	p-Bromochlorobenzene	64.6	98	18.75	I	(51)
C <sub>5</sub> H <sub>4</sub> BrI	o-Bromiodobenzene	21	51	14.45	I	(51)
	m-Bromiodobenzene	-9.3	43	12.2	I	(51)
	p-Bromiodobenzene	90.1	69.5	19.65	I	(51)
C <sub>5</sub> H <sub>4</sub> Br <sub>2</sub>	o-Dibromobenzene	18	53.5	12.6	I	(51)
	m-Dibromobenzene	-6.9	56	13.2	I	(51)
	p-Dibromobenzene	86 ± 1	86 ± 1	20.3	B†	(9, 10)
C <sub>5</sub> H <sub>4</sub> Br <sub>2</sub> O	2, 4-Dibromophenol	12	58.5	14.75	C	(83)
C <sub>5</sub> H <sub>4</sub> Br <sub>3</sub> N	2, 4, 6-Tribromoaniline	122	70.5	23.25	B	(64)
C <sub>5</sub> H <sub>4</sub> ClNO <sub>2</sub>	m-Chloronitrobenzene	43.8	123	19.4	B	(10)
		44.16	131.9	20.775	B	(9)
	p-Chloronitrobenzene	82	89.5	14.1	B	(10)
C <sub>5</sub> H <sub>4</sub> Cl <sub>2</sub>	o-Dichlorobenzene	-17.5	88	12.9	I	(51)

\* Also C (25, 56) and G (50). † Heat of crys. at 0°. ‡ Also I (51).



Formula	Name	M. P., °C	Joule per g	Kilojoule per g-formula-wt.	Method	Lit.
$C_6H_4Cl_2$	<i>m</i> -Dichlorobenzene.....	-24.4	86	12.6	I	(51)
	<i>p</i> -Dichlorobenzene.....	52.7 ± 0.2	124.2 ± 0.8	18.25	B	(10)
					I	(51)
$C_6H_4I_2$	<i>o</i> -Diiodobenzene.....	23.4	42.5	14.1	I	(51)
	<i>m</i> -Diiodobenzene.....	34.2	48.35	15.95	I	(51)
	<i>p</i> -Diiodobenzene.....	129	67.8	22.4	I	(51)
$C_6H_4N_2O_4$	<i>o</i> -Dinitrobenzene.....	116.93	135.0 ± 4	22.84	B	(1.4)
	<i>m</i> -Dinitrobenzene.....	90.08	103.4 ± 4	17.36	B	(1.4)
	<i>p</i> -Dinitrobenzene.....	173.5	167.4 ± 4	28.1	B	(1.4)
$C_6H_4O_2$	Quinone.....	112.85 ± 0.5	171.0 ± 4	18.46	B	(46.5)
$C_6H_5BrO$	<i>p</i> -Bromophenol.....	64	85.8 ± 1.3	14.85	C	(83)
$C_6H_5NO_2$	Nitrobenzene.....	5.72 ± 0.10	94.25 ± 0.25	11.6	G, I	(50, 76)
$C_6H_5NO_2$	<i>o</i> -Nitrophenol.....	42.8	112	15.6	B	(10)
		44.51	129.35	17.98	B	(9)
$C_6H_6$	Benzene.....	5.42 ± 0.02	127.0 ± 1.4	9.91	A*	(9, 14)
						(22, 48)
		5.40	126.5 ± 4	9.88	B	(1.4)
$C_6H_5ClN$	<i>p</i> -Chloroaniline.....	69	155.5	19.83	B	(10)
$C_6H_5N_2O_2$	<i>o</i> -Nitroaniline.....	69.3	116.7	16.12	B	(1.4)
	<i>m</i> -Nitroaniline.....	111.8	171.5	23.70	B	(1.4)
	<i>p</i> -Nitroaniline.....	147.5	152.6	21.10	B	(1.4)
$C_6H_5O$	Phenol.....	25.37	121.5	11.4	E	(74)
$C_6H_5O_2$	<i>o</i> -Dihydroxybenzene.....	104.3	206.8	22.76	B	(1.4)
	<i>m</i> -Dihydroxybenzene.....	109.65 ± 0.5	193.4	21.29	B	(1.4, 67)
	<i>p</i> -Dihydroxybenzene.....	172.3	246.0	21.70	B	(1.4)
$C_6H_7N$	Aniline.....	-7.03	87.7	8.16	A	(25)
$C_6H_5N_2$	Phenylhydrazine.....	22.1	152.0 ± 0.6	16.43	A	(46)
$C_6H_5O_4$	Methyl fumarate.....	102	242.5	34.95	B	(53)
$C_6H_{10}O_4$	Methyl succinate.....	18	149.55	21.84	B	(53)
$C_6H_{10}O_4$	<i>dl</i> -Dimethyl tartrate.....	87	147	26.2	F	(77)
	<i>d</i> -Dimethyl tartrate.....	49	90	16	F	(77)
$C_6H_{12}O$	Cyclohexanol.....	23.2 ± 0.8	17.55 ± 0.3	1.756	B, C	(26, 85)
$C_6H_{12}O_2$	Paraldehyde.....	12.6	104.75	13.83	A	(46)
$C_7H_5ClO_2$	<i>o</i> -Chlorobenzoic acid.....	140.2	164.5 ± 4	25.76	B	(46.5)
	<i>m</i> -Chlorobenzoic acid.....	154.25	152.4 ± 4	23.86	B	(46.5)
	<i>p</i> -Chlorobenzoic acid.....	239.7	206 ± 4	32.3	B	(46.5)
$C_7H_5NO_4$	<i>o</i> -Nitrobenzoic acid.....	145.8	167.7 ± 4	28.02	B	(46.5)
	<i>m</i> -Nitrobenzoic acid.....	141.1	115.5 ± 4	19.30	B	(46.5)
	<i>p</i> -Nitrobenzoic acid.....	239.2	221.0 ± 4	36.90	B	(46.5)
$C_7H_5N_3O_4$	2, 4, 6-Trinitrotoluene.....	79	93.5 ± 3.5	21.23	I	(14.2, 76)
$C_7H_5N_2O_4$	2, 4-Dinitrotoluene.....	70	110.5	20.1	I	(76)
$C_7H_5O_2$	Benzoic acid.....	121.8	141.9 ± 4	17.3	B	(46.5)
$C_7H_7Br$	<i>p</i> -Bromotoluene.....	27.6 ± 1.2	87.3 ± 3	14.93	B	(56)
					A	(46)
$C_7H_7I$	<i>p</i> -Iodotoluene.....	34	78.5	17.1	I	(76)
$C_7H_7NO_2$	<i>o</i> -Aminobenzoic acid.....	145	148.5 ± 4	20.38	B	(1.4)
	<i>m</i> -Aminobenzoic acid.....	180	159.2 ± 4	21.83	B	(1.4)
	<i>p</i> -Aminobenzoic acid.....	188.5	152.6 ± 4	20.91	B	(1.4)
$C_7H_8O$	<i>p</i> -Cresol.....	34	110	11.9	B	(10)
$C_7H_8O_2$	Dimethyl- $\gamma$ -pyrone.....	132	235	29	B	(59)
$C_7H_9N$	<i>p</i> -Toluidine.....	40.01 ± 0.12	167.0 ± 2.4	17.88	B	(2, 14)
$C_8H_6Cl_4$	<i>o</i> -Tetrachloroxylene.....	86	88	21.45	I	(13)
	<i>p</i> -Tetrachloroxylene.....	95	92.5	22.55	I	(13)
$C_8H_6Br_2$	<i>o</i> -Xylene dibromide.....	95	101.5	26.79	I	(13)
	<i>m</i> -Xylene dibromide.....	77	89.8	23.7	I	(13)
$C_8H_6Cl_2$	<i>o</i> -Xylene dichloride.....	55	121.5	21.25	I	(13)
	<i>m</i> -Xylene dichloride.....	34	111.5	19.55	I	(13)
	<i>p</i> -Xylene dichloride.....	100	137	23.95	I	(13)
$C_8H_8O_2$	Phenylacetic acid.....	74.9	106.5	14.45	B	(10)
		76.58	125.6	17.09	B	(9)
		77	134	18.2	B	(64)

\* Also I(21), G(50), B(53), A(9).



Formula	Name	M. P., °C	Joule per g	Kilojoule per g-formula-wt.	Method	Lit.
$C_8H_8O_2$	<i>o</i> -Tolule acid.....	103.7	148.2 ± 4	20.18	B	(1.4)
	<i>m</i> -Tolule acid.....	108.75	115.5 ± 4	15.74	B	(1.4)
	<i>p</i> -Toluic acid.....	179.6	167 ± 4	22.71	B	(1.4)
$C_8H_9NO_2$	Hydroxyacetanilide.....	91.3 ± 0.1	140.6	21.26	B	(1.4)
$C_8H_{10}$	<i>p</i> -Xylene.....	16.	164.5	17.45	I	(13)
$C_8H_{10}O_2$	Veratrol.....	22.7	114.9 ± 1.25	15.87	B, A	(46, 64)
$C_8H_{16}O_2$	<i>n</i> -Caprylic acid.....	16.34	148.2	21.36	B	(27)
$C_9H_8O_2$	Allocinnamic acid.....	58	114.5	17		(65)
$C_9H_8O_2$	Cinnamic acid.....	133	152.85	22.635	B	(53)
$C_9H_{10}O_2$	Hydrocinnamic acid.....	48	117.75	32.74	B	(53)
$C_9H_{18}O_2$	<i>n</i> - $\alpha$ -Pelargonic acid.....	12.35	128.2	20.27	B	(27)
	<i>n</i> - $\beta$ -Pelargonic acid.....		163.4	25.84	B	(27)
$C_{10}H_7NO_2$	$\alpha$ -Nitronaphthalene.....	56	106.5	18.43	B	(2)
$C_{10}H_8$	Naphthalene.....	79.9 ± 1.1	148.9 ± 0.4	19.07	B	(1, 2, 46.5, 53, 57)
$C_{10}H_8O$	$\alpha$ -Naphthol.....	95	163 ± 4	23.5	B	(46.5)
	$\beta$ -Naphthol.....	120.6	131 ± 4	18.8	B	(46.5)
$C_{10}H_8O_2$	Methyl phenylpropiolate.....	18	95.75	15.325	B	(53)
$C_{10}H_9N$	$\alpha$ -Naphthylamine.....	47.5	93.5	13.35	B	(10)
		48.9	92.05	13.17	B	(14)
		50.1	107.1 ± 0.8	15.33	B	(71)
$C_{10}H_{10}$	1, 4-Dihydronaphthalene.....	150	21.85	2.84	I	(76)
$C_{10}H_{10}O_2$	Methyl cinnamate.....	34.5 ± 1.5	111 ± 1.5	17.99	I, B	(53, 76)
$C_{10}H_{12}O$	Anethole.....	21.5	108.0 ± 1.3	16 ± 0.19	B	(46)
$C_{10}H_{14}O$	Thymol.....	48.5	115	17.3	B	(19)
$C_{10}H_{16}BrO$	Bromocamphor.....		174	40.2	B	(2)
$C_{10}H_{16}NO$	<i>d</i> -Carvoxime.....	71.5	97.5	16.1	F	(77)
	<i>l</i> -Carvoxime.....	71	98	16.15	F	(77)
	<i>dl</i> -Carvoxime.....	91	103	17.0	F	(77)
$C_{10}H_{20}O$	<i>l</i> - $\alpha$ -Menthhol.....	42	78 ± 1	12.2	B	(10)
$C_{10}H_{20}O_2$	<i>n</i> -Capric acid.....	31.2	162.7	28.01	B	(27)
$C_{11}H_{22}O_2$	<i>n</i> -Undecylic acid( $\alpha$ ).....	28.25	134.8	25.09	B	(27)
	<i>n</i> -Undecylic acid( $\beta$ ).....		179.6	33.43	B	(27)
$C_{12}H_8N$	Carbazole.....	236	176	29.45	I	(76)
$C_{12}H_{10}$	Diphenyl.....	71	109.2 ± 0.6	16.84	B	(82)
$C_{12}H_{10}N_2$	Azobenzene.....	69.1	121	22.1	B	(19)
		66	117	21.25	B	(10)
		68	135.6	24.69	B	(53)
$C_{12}H_{10}N_2O$	Azoxybenzene.....	34.6	90.5	17.9	B	(10)
$C_{12}H_{11}N$	Diphenylamine.....	53.4 ± 0.6	105.6 ± 5.3	17.86	B	(9, 71)
$C_{12}H_{12}N_2$	Hydrazobenzene.....	134	95.75	17.63	I	(76)
$C_{12}H_{14}O_4$	Apiol.....	29.26	108.0 ± 0.2	23.99	B	(75)
$C_{12}H_{24}O_2$	<i>n</i> -Lauric acid.....	43.85 ± 0.15	183 ± 2	36.63	B	(72)
					B	(27)
$C_{13}H_{10}O$	Benzophenone.....	48.25 ± 0.25	98.5 ± 0.55	17.95	B	(10, 75)
$C_{13}H_{12}$	Diphenylmethane.....	26.3	105.5	17.7	I	(76)
$C_{13}H_{13}N$	Benzylaniline.....	36	91.5	16.75	I	(76)
$C_{14}H_8O_2$	Anthraquinone.....	282	156.9 ± 1.2	32.64	B	(39)
$C_{14}H_{10}$	Anthracene.....	216.55	162 ± 0.4	28.85	B	(39)
$C_{14}H_{10}$	Phenanthrene.....	98.2 ± 1.8	101.5 ± 2.5	18.1	B	(64)
$C_{14}H_{10}$	Tolane.....	60	120.05	21.38	B	(53)
$C_{14}H_{10}O_2$	Benzil.....	94.94	92.7	19.45	B	(9)
$C_{14}H_{12}$	Dihydrophenanthrene.....	94	73.45	13.25	B	(53)
$C_{14}H_{12}$	Stilbene.....	124	167	30.2	I	(76)
$C_{14}H_{14}$	Dibenzyl.....	51	129.85	23.645	I	(76)
$C_{14}H_{22}O_2$	Myristic acid.....		198.75	45.35	B	(72)
$C_{15}H_{32}O_2$	Palmitic acid.....	55	164	42.05	B	(10)
$C_{15}H_{34}O$	Cetyl alcohol.....	47	141.5	34.25	I	(76)
$C_{15}H_{14}O_2$	Cinnamic anhydride.....	48	117.75	32.74	B	(53)
$C_{15}H_{34}O_2$	Elaidic acid.....	47	218	61.55	I	(76)
$C_{15}H_{36}O_2$	Stearic acid.....	64	199	56.5	B	(10)
$C_{15}H_{16}$	Triphenylmethane.....	92.3	74.5 ± 0.8	18.2	B	(39)
$C_{17}H_{34}O_2$	Tristearin.....	56	191	170	I	(76)



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- (70) Simon and Lange, 96, 15: 312; 23. (71) Stillmann and Swain, 7, 29: 705; 99. (72) Stohmann and Wilsing, 52, 32: 80; 85. (73) Stortenbeker, 7, 10: 183; 92. (74) Stratton and Partington, 3, 42: 436; 22. (75) Tammann, 7, 29: 51; 99. (76) Tammann, 188, 1913: 335. 7, 85: 273; 13. (77) Tammann, 7, 87: 357; 14. (78) Thomsen, 223, II: 212. (79) Tollocsko, 165, 1901A: 1.
- (80) de Visser, 70, 12: 101; 93. (81) Walden, 93, 68: 307; 10. (81.5) Wartenberg, 13, 440: 97; 24. (82) Washburn and Read, 197, 1: 191; 15. (83) Werner, 6, 3: 567; 84. (84) Wigand, 7, 63: 273; 08. (85) Cauquil, 34, 180: 1208; 25. (86) Giauque and Wiebe, 1, 50: 101; 28. (87) Giauque and Wiebe, 1, 50: 2193; 28. (88) Magnus and Oppenheim, 93, 168: 305; 28. (89) Roberts, 182, 18: 139; 03.
- (90) Umino, 47, 28: 381; 28.

## LATENT HEAT OF VAPORIZATION

The values recorded in this section are based upon direct calorimetric determinations. For values based upon vapor pressure data, see the vapor pressure sections of Vol. III, p. 201, 204, 207, 213, 215, 302, and for metals, v. Vol. II, p. 458; Vol. III, p. 204.

## CONVERSION FACTORS

1 joule = 0.2392 g-cal<sub>15</sub>; = 0.2389 g-cal<sub>18</sub>; =  $2.778 \times 10^{-7}$  kw. hr; = 0.7376 ft. lb.; =  $9.870 \times 10^{-3}$  l-atm.; =  $9.482 \times 10^{-4}$  BTU<sub>40</sub>.

## ELEMENTARY SUBSTANCES AND ATMOSPHERIC AIR\*

ARTHUR WHITMORE SMITH

Symbol	<i>l</i> , g-cal <sub>15</sub> per g	<i>L</i> , kj per g-atom	At <i>t</i> , °C or <i>p</i> , mm	Lit.
A.....	37.6	6.28	-186°	(10, 14)
Br.....	43.7(?)	14.6(?)	+ 63°	(6, 19)
H <sub>2</sub> .....	108	0.455	-252.8°	(10)
H <sub>2</sub> .....	108	0.455	760 mm	(13)
H <sub>2</sub> .....	109.2	0.460	600 mm	(14)
H <sub>2</sub> .....	110.8	0.467	400 mm	(17)
H <sub>2</sub> .....	112.2	0.473	200 mm	(22)
He.....	6	0.100	-268.6°	(15, 16)
I <sub>2</sub> .....	24(?)	12.7	+184°	(11)
N <sub>2</sub> .....	47.6	2.790	-195.55°	(1)
N <sub>2</sub> .....	48.3	2.830	-198°	(10)
N <sub>2</sub> .....	49.4	2.900	-202°	(14)
N <sub>2</sub> .....	50.5	2.960	-206°	
N <sub>2</sub> .....	51.6	3.025	-210°	
O <sub>2</sub> .....	50.9	3.410	-182.9°	(1)
O <sub>2</sub> .....	52.0	3.480	-188°	(2)
O <sub>2</sub> .....	53.2	3.560	-194°	(10)
O <sub>2</sub> .....	54.5	3.650	-200°	(13)
O <sub>2</sub> .....	55.5	3.720	-205°	
P.....	130	17.0	+287°	(12)
S.....				(1.5)

\* For metals, v. Vol. II, p. 458; Vol. III, p. 204.

## OXYGEN-NITROGEN MIXTURES UNDER ONE ATMOSPHERE

The quantity recorded below is the difference in heat content between the liquid at its boiling point and a vapor of the same composition at its initial condensation temperature. Accuracy: 0.2 % absolute, 0.1 % relative (7.5).

% O <sub>2</sub> in liq.....	0	5	10	15	20	25	30
<i>l</i> , joule/g.....	119.8	201.1	202.4	203.7	204.9	206.2	207.4
% O <sub>2</sub> in liq.....	35	40	45	50	55	60	65
<i>l</i> , joule/g.....	208.5	209.5	210.4	211.2	212.0	212.7	213.3
% O <sub>2</sub> in liq.....	70	75	80	85	90	95	100
<i>l</i> , joule/g.....	213.7	214.1	214.4	214.4	214.1	213.9	213.4

## LITERATURE

(For a key to the periodicals see end of volume)

- (1) Alt, 8, 19: 739; 06. (1.5) Awbery, 67, 29: 417; 27. (2) Barschall, 9, 17: 345; 11. (3) Baxter and Grose, 1, 37: 1061; 15. (4) Baxter, Hickey and Holmes, 1, 29: 127; 07. (5) Beckmann and Liesche, 93, 85: 31; 14. (6) Berthelot and Ogier, 6, 30: 410; 83. (7) Crommelin, 64P, 16: 477; 13. 168, No. 122c; 13. (7.5) Dana, 65, 60: 241; 25. (8) Dewar, 182, 14: 241; 99. (9) Dodd, 1, 42: 1579; 20.
- (10) Eucken, 20, 18: 4; 16. (11) Favre and Silbermann, 6, 37: 406; 53. (12) Kaye and Laby, Physical and chemical constants and some tables of mathematical functions, New York, Longmans, 1921. (13) Keesom, 168, No. 137e; 11. (14) Mathias, Crommelin and Onnes, 34, 176: 939; 23. (15) Onnes, 64P, 13: 1093; 11. 168, No. 119: 11. (16) Onnes, 63, p. 7475. (17) Onnes and Keesom, 64P, 16: 440; 13. 168, No. 137d; 13. (18) Pellaton, 42, 13: 426; 15. (19) van der Plaats, quoted by (12).
- (20) Richards, 145, 187: 581; 19. (21) Shearer, 2, 17: 469; 03. (22) Simon and Lange, 96, 15: 312; 23.

## CHEMICAL COMPOUNDS

FARRINGTON DANIELS AND J. HOWARD MATHEWS

*l*, = latent heat of vaporization, joules per gram, at *t*, °C to produce saturated vapor at *t*°, the liquid being under its own vapor pressure during evaporation.

The values marked with an asterisk (\*) were obtained by measuring the heat of condensation. All other values were obtained by measuring the input of electrical energy necessary to evaporate a given weight of liquid.

The results by condensation methods (\*) are usually too low on account of premature condensation and are unreliable also, because the specific heat of the liquid is usually not accurately known. Most of the results published before 1900 may be too low by 10 joules or more.

For the substances marked with a dagger (†) the value given is taken from the detailed tables of the next section, p. 138.



Parentheses ( ) around the temperature indicate that the temperature was not recorded in the original communication and that the normal boiling point has been taken. The corresponding value of Trouton's ratio is also enclosed in parentheses.

$l_v$  = chaleur latente de vaporisation, joules par g à  $t$ , °C nécessaires pour produire la vapeur saturée à  $t$ , le liquide étant sous sa propre tension de vapeur pendant l'évaporation.

Les valeurs marquées d'un astérisque (\*) ont été obtenues en mesurant la chaleur de condensation. Toutes les autres valeurs ont été obtenues en mesurant l'apport d'énergie électrique, nécessaire pour évaporer un poids donné de liquide.

Les résultats obtenus par les méthodes de condensation (\*) sont ordinairement trop faibles par le fait d'une condensation prématurée et sont aussi moins dignes de confiance par le fait que la chaleur spécifique du liquide n'est généralement pas connue d'une façon précise. La plupart des résultats publiés avant 1900 peuvent être trop faibles de 10 joules et plus.

Pour les substances marquées d'une croix (†), la valeur donnée est extraite des tables détaillées de la section suivante, p. 138.

La température marquée entre parenthèses ( ) indique que la température n'a pas été mentionnée dans le mémoire original et que le point d'ébullition normal a été choisi. La valeur correspondante du rapport de Trouton est aussi mise entre parenthèses.

$l_v$  = latente Wärme der Verdampfung, in Joule pro Gramm bei  $t$ , °C für die Erzeugung von gesättigten Dampf bei  $t$ . Während der Verdampfung befindet sich die Flüssigkeit unter ihrem eigenen Dampfdruck.

Die mit einem Stern (\*) bezeichneten Werte sind durch Messung der Kondensations-Wärme erhalten worden. Alle anderen Werte sind durch Messung der angewandten elektrischen Energie erhalten, die notwendig ist, eine gegebene Gewichtsmenge Flüssigkeit zu verdampfen.

Die nach der Kondensationsmethode (\*) erhaltenen Werte sind gewöhnlich zu niedrig, einmal wegen der vorzeitigen Kondensation, dann aber auch deshalb, weil die spezifische Wärme der Flüssigkeit gewöhnlich nicht genau bekannt ist. Viele der Werte die vor dem Jahre 1900 publiziert worden sind, dürften deshalb um etwa 10 oder mehr Joule zu niedrig sein.

Für die mit einem Schwert (†) bezeichneten Stoffe ist der angegebene Wert einer besonderen Tabelle des folgenden Abschnittes, S. 138, entnommen.

Die in Klammer ( ) gesetzten Temperaturen bedeuten, dass diese nicht in der Originalmitteilung angegeben ist und der normale Siedepunkt genommen ist. Der entsprechende Trouton'sche Quotient ist ebenfalls in Klammer gesetzt.

$l_v$  = calore latente di vaporizzazione, joules per g necessari a  $t$ , °C per produrre vapore saturo a  $t$ , supponendo il liquido durante l'evaporazione sotto la sua tensione di vapore.

I valori segnati con un asterisco (\*) sono stati ottenuti misurando il calore di condensazione. Tutti gli altri sono stati ricavati dal consumo di energia elettrica necessaria ad evaporare un dato peso di liquido.

I risultati ottenuti con il metodo di condensazione (\*) sono per lo più troppo bassi a causa di una condensazione prematura e sono incerti anche perchè il calore specifico dei liquidi in genere, non è esattamente conosciuto. La massima parte dei risultati pubblicati prima del 1900, possono essere più bassi di 10 joules o anche più.

Per le sostanze segnate con (†) il valore dato è preso dalle tabelle riportate nella sezione seguente a p. 138.

Le temperature chiuse tra parentesi ( ) significano che non trovandosi indicata la temperatura nella memoria originale si è preso il punto di ebollizione normale. Il valore corrispondente del rapporto di Trouton è anche chiuso tra parentesi.

$$\text{Trouton's ratio, } \frac{L_v}{T} = \frac{Ml_v}{273.1 + t}$$

B-TABLE

Formula	$t$ , °C	$l_v$ at $t$ , °C, joule per gram	Trouton's ratio, $L_v/T$	Lit.
H <sub>2</sub> O†	100	2258	109.0	v. p. 138
HF	17	1510	104	(23)*
HCl	- 84.3	413.1	79.8	(23)
	- 85.0	443.1	85.8	(28.5)
HBr	- 69.9	203.6	81.2	(23)
	- 66.72	217.7	85.3	(81)
HI	- 37.2	142.0	77.1	(23)
SO <sub>2</sub> †	- 10.08	397	96.7	v. p. 138
SO <sub>2</sub>	53	496	122.1	(29)*
H <sub>2</sub> S	- 61.4	552.2	88.9	(23)
H <sub>2</sub> SO <sub>4</sub>	326	511	83.7	(66)*
S <sub>2</sub> Cl <sub>2</sub>	138	207	67.6	(62)*
	138	267	87.7	(32.5)
SOCl <sub>2</sub>	82	228	76.4	(62)*
SO <sub>2</sub> Cl <sub>2</sub>	69.1	206.9	81.6	(74)*
S <sub>2</sub> O <sub>2</sub> Cl <sub>2</sub>	140	256	133.3	(63)*
ClSO <sub>3</sub> H	151	461	126.7	(63)*
NH <sub>3</sub> †	- 33.4	1369	98.1	v. p. 138
HNO <sub>3</sub>	86.0	481	84.4	(6)*
N <sub>2</sub> O†				v. p. 138
N <sub>2</sub> O <sub>4</sub>	18	391	123.6	(14)*
NH <sub>4</sub> Cl (solid)	350	330		(52)*
PCl <sub>3</sub>	78	216	84.2	(1)*
Si(OCH <sub>3</sub> ) <sub>4</sub>	121	194	75.0	(40)
Si(OC <sub>2</sub> H <sub>5</sub> ) <sub>4</sub>	156	141	42.5	(61)*
CO	(-192)	211.1	(73.0)	(24)
CO <sub>2</sub> †				v. p. 138
SiCl <sub>4</sub>	57	151	77.7	(40)
SnCl <sub>4</sub>	112	127	85.9	(1)*
BCl <sub>3</sub>	10	166	66.3	(8)*

C-TABLE—C-Arrangement (v. Vol. III, p. viii)

Formula	Name	$t$ , °C	$l_v$ at $t$	$L_v/T$	Lit.
CClN	Cyanogen chloride	13	568	121.4	(9)*
CCl <sub>4</sub> †	Carbon tetrachloride	76.75	194.3	85.4	v. p. 138
CS <sub>2</sub> †	Carbon disulfide	46.25	352	83.8	v. p. 138
CHCl <sub>3</sub> †	Chloroform	61.5	247	87.9	v. p. 138
CHN	Hydrocyanic acid	20	880	81.1	(9)*
CH <sub>2</sub> Cl <sub>2</sub>	Methylene chloride	40.5	329	89.1	(87)
CH <sub>3</sub> O <sub>2</sub>	Formic acid	101	502	61.8	(15)
CH <sub>3</sub> Cl	Methyl chloride	- 23.8	428	75.1	(73)
		+ 15.0	402		(79.5)
		20.0	399		(79.5)
		25.0	396		(79.5)
CH <sub>3</sub> I	Methyl iodide	(42)	192	(86.5)	(84)
CH <sub>3</sub> NO <sub>2</sub>	Nitromethane	99.9	565	92.5	(87)
CH <sub>4</sub>	Methane	- 159	578	81.0	(67)
CH <sub>3</sub> O†	Methyl alcohol	64.7	1100	104.3	v. p. 138
C <sub>2</sub> Cl <sub>4</sub>	Tetrachloroethylene	120.7	209.5	88.2	(87)
C <sub>2</sub> N <sub>2</sub>	Cyanogen	0	431	82.1	(19)*
C <sub>2</sub> HCl <sub>3</sub>	Trichloroethylene	85.7	239.6	87.8	(87)
C <sub>2</sub> HCl <sub>2</sub> O	Chloral		226		(7)*
C <sub>2</sub> H <sub>3</sub> Cl <sub>3</sub> O <sub>2</sub>	Dichloroacetic acid	194.4	323	89.1	(47)*
C <sub>2</sub> H <sub>2</sub> Cl <sub>4</sub>	1, 1, 2, 2-Tetrachloroethane	145.0	230.5	92.6	(87)
C <sub>2</sub> H <sub>2</sub> ClO	Acetyl chloride	(51)	330	(79.9)	(11)*
C <sub>2</sub> H <sub>2</sub> Cl <sub>2</sub> O <sub>2</sub>	Chloral hydrate	96	552	274.4	(7)*
C <sub>2</sub> H <sub>3</sub> N	Acetonitrile	80	727	84.5	(88)*
C <sub>2</sub> H <sub>4</sub> Br <sub>2</sub>	Ethylene bromide	130.8	193.5	90.0	(87)
C <sub>2</sub> H <sub>4</sub> Cl <sub>2</sub>	Ethylene chloride	0.0	357		(86)*
		82.3	323.7	90.1	(87)
C <sub>2</sub> H <sub>4</sub> Cl <sub>2</sub>	Ethylidene chloride	0.0	321		(86)*
		(60)	281	(83.5)	(19)*
C <sub>2</sub> H <sub>4</sub> O	Acetaldehyde	(21)	570	(85.3)	(4)*
C <sub>2</sub> H <sub>4</sub> O	Ethylene oxide	13	580	89.3	(10)*
C <sub>2</sub> H <sub>4</sub> O <sub>2</sub> †	Acetic acid	118.3	405	62.1	v. p. 138
C <sub>2</sub> H <sub>4</sub> O <sub>2</sub>	Methyl formate	31.3	470.3	92.8	(87)



C-TABLE.—(Continued)

Formula	Name	$t, ^\circ\text{C}$	$t, \text{at } ^\circ\text{F}$	$L_v/T$	Lit.
$\text{C}_2\text{H}_5\text{Br}$	Ethyl bromide.....	38.4	250.8	87.8	(76)
$\text{C}_2\text{H}_5\text{Cl}$	Ethyl chloride.....	4.7	389	90.3	(37)
		15.0	387	86.6	(79.5)
		20.0	386		(79.5)
		25.0	385		(79.5)
$\text{C}_2\text{H}_5\text{ClO}$	2-Chloroethyl alcohol....	126.5	514.6	103.7	(57)
$\text{C}_2\text{H}_5\text{I}$	Ethyl iodide.....	71.2	190.9	86.5	(57)
$\text{C}_2\text{H}_6$	Ethane.....	0	314		(19.5)
		- 10	341		(19.5)
		- 20	364		(19.5)
		- 30	386		(19.5)
		- 40	408		(19.5)
		- 90	1080	177.3	(67)
$\text{C}_2\text{H}_5\text{O}^\dagger$	Ethyl alcohol.....	78.3	855	112.0	v. p. 138
$\text{C}_2\text{H}_5\text{O}_2$	Glycol.....	197	800	105.6	(48)*
$\text{C}_2\text{H}_7\text{N}$	Ethylamine.....	(15)	611	(95.5)	(28)*
$\text{C}_2\text{H}_5\text{N}$	Propionitrile.....	97	562	83.6	(47)*
$\text{C}_2\text{H}_5\text{O}^\dagger$	Acetone.....	56.1	521	91.9	v. p. 138
$\text{C}_2\text{H}_5\text{O}$	Allyl alcohol.....	(96)	684	(107.5)	(46)*
$\text{C}_2\text{H}_5\text{O}_2$	Ethyl formate.....	53.3	406.8	92.3	(57)
$\text{C}_2\text{H}_5\text{O}_2$	Methyl acetate.....	0.0	477		(36)*
		56.3	410.6	92.3	(57)
$\text{C}_2\text{H}_5\text{O}_2$	Propionic acid.....	139.3	413.6	74.3	(57)
$\text{C}_2\text{H}_5\text{O}_2$	Dimethyl carbonate.....	90	369	91.5	(46)*
$\text{C}_2\text{H}_6$	Propane.....	20	349		(19.5)
		+ 10	362		(19.5)
		0	375		(19.5)
		- 10	387		(19.5)
		- 20	399		(19.5)
		- 30	410		(19.5)
$\text{C}_2\text{H}_5\text{O}^\dagger$	n-Propyl alcohol.....	97.2	688	111.6	v. p. 138
$\text{C}_2\text{H}_5\text{O}^\dagger$	Isopropyl alcohol.....	82.3	667	118.4	v. p. 138
$\text{C}_2\text{H}_5\text{O}_2$	Methylal.....	42	376	90.8	(12)*
$\text{C}_2\text{H}_4\text{O}$	Furane.....	31	399	89.3	(57.2)
$\text{C}_2\text{H}_5\text{O}_2$	Acetic anhydride.....	137	277	68.9	(4)*
$\text{C}_2\text{H}_7\text{ClO}_2$	$\beta$ -Chloroethyl acetate....	141.5	338	99.9	(57)
$\text{C}_2\text{H}_7\text{N}$	n-Butyronitrile.....	117.4	481	85.1	(49)*
$\text{C}_2\text{H}_5\text{O}$	Methyl ethyl ketone.....	78.2	443.4	91.0	(57)
$\text{C}_2\text{H}_5\text{O}_2$	n-Butyric acid.....	163.5	477	96.2	(15)
$\text{C}_2\text{H}_5\text{O}_2$	Isobutyric acid.....	154	467	96.3	(15)
$\text{C}_2\text{H}_5\text{O}_2$	Ethyl acetate.....	0.0	427		(36)*
$\text{C}_2\text{H}_5\text{O}_2$	Methyl propionate.....	79.0	366.5	91.7	(57)
$\text{C}_2\text{H}_5\text{O}_2$	n-Propyl formate.....	80.0	368.9	92.0	(57)
$\text{C}_2\text{H}_5\text{I}$	n-Butyl iodide.....	129.5	192.1	87.8	(57)
$\text{C}_2\text{H}_5\text{NO}$	Methyl ethyl ketoxime....	182	485	92.8	(49)*
$\text{C}_2\text{H}_6$	Butane.....	20	366		(19.5)
		10	376		(19.5)
		0	383	81.4	(19.5)
$\text{C}_4\text{H}_{10}$	Isobutane.....	20	333		(19.5)
		+ 10	345		(19.5)
		0	356		(19.5)
		- 10	366	80.8	(19.5)
$\text{C}_4\text{H}_{10}\text{O}$	n-Butyl alcohol.....	116.8	591.8	112.4	(57)
$\text{C}_4\text{H}_{10}\text{O}$	Isobutyl alcohol.....	106.9	578	112.7	(57)
$\text{C}_4\text{H}_{10}\text{O}$	sec.-Butyl alcohol.....	98.1	562.5	112.3	(57)
$\text{C}_4\text{H}_{10}\text{O}$	tert.-Butyl alcohol.....	83	546	113.6	(15)
$\text{C}_4\text{H}_{10}\text{O}^\dagger$	Ethyl ether.....	34.6	351	84.5	v. p. 138
$\text{C}_4\text{H}_{11}\text{N}$	Diethylamine.....	58	381	84.1	(59)*
$\text{C}_4\text{H}_6\text{O}_2$	Furfural.....	160.5	450	99.6	(57)
$\text{C}_4\text{H}_5\text{N}$	Pyridine.....	114.1	449.4	91.8	(57)
$\text{C}_4\text{H}_5\text{N}$	n-Valeronitrile.....	129	403	83.3	(39)*
$\text{C}_4\text{H}_{10}$	Amylene.....	12.5	314	77.1	(5)*
$\text{C}_4\text{H}_{10}\text{O}$	Diethyl ketone.....	101	380	87.5	(46)*
$\text{C}_4\text{H}_{10}\text{O}$	Methyl isopropyl ketone....	92	376	88.7	(46)*
$\text{C}_4\text{H}_{10}\text{O}_2$	n-Butyl formate.....	105.1	363.1	98.0	(57)
$\text{C}_4\text{H}_{10}\text{O}_2$	Isobutyl formate.....	97.0	328.6	90.7	(57)
$\text{C}_4\text{H}_{10}\text{O}_2$	Ethyl propionate.....	97.6	335.2	92.3	(57)
$\text{C}_4\text{H}_{10}\text{O}_2$	Methyl n-butyrate.....	102.6	334	90.8	(15)
$\text{C}_4\text{H}_{10}\text{O}_2$	Methyl isobutyrate.....	91.1	327.0	91.7	(57)
$\text{C}_4\text{H}_{10}\text{O}_2$	n-Propyl acetate.....	100.4	336.0	91.9	(57)
$\text{C}_4\text{H}_{10}\text{O}_2$	n-Valeric acid.....	184.6	432	96.4	(15)
$\text{C}_4\text{H}_{10}\text{O}_2$	Isovaleric acid.....	176.3	423	96.1	(15)
$\text{C}_4\text{H}_{10}\text{O}_2$	Diethyl carbonate.....	126	306	90.6	(47)*
$\text{C}_4\text{H}_{11}\text{Br}$	n-Amyl bromide.....	129	202	(75.9)	(9)*
$\text{C}_4\text{H}_{11}\text{I}$	n-Amyl iodide.....	155	199	(92.1)	(9)*
$\text{C}_4\text{H}_{11}\text{N}$	Piperidine.....	106	374	84.0	(47)*
$\text{C}_4\text{H}_{12}$	Isopentane.....	13	371	93.5	(75)
$\text{C}_4\text{H}_{12}\text{O}$	n-Amyl alcohol.....	131	503	109.7	(68)*
$\text{C}_4\text{H}_{12}\text{O}$	Isoamyl alcohol.....	130.2	501.4	109.3	(57)

C-TABLE.—(Continued)

Formula	Name	$t, ^\circ\text{C}$	$t, \text{at } ^\circ\text{F}$	$L_v/T$	Lit.
$\text{C}_5\text{H}_{12}\text{O}$	tert.-Amyl alcohol.....	102	443	104.1	(16)
$\text{C}_5\text{H}_{12}\text{O}$	Ethyl propyl ether.....	60.0	346	91.5	(69)
$\text{C}_5\text{H}_{13}\text{N}$	n-Amylamine.....	95	413	97.8	(38)*
$\text{C}_5\text{H}_5\text{Br}$	Bromobenzene.....	155.9	241.1	88.2	(57)
$\text{C}_5\text{H}_5\text{Cl}$	Chlorobenzene.....	130.6	324.8	90.5	(57)
$\text{C}_5\text{H}_5\text{NO}_2$	Nitrobenzene.....	210	331	84.3	(49)*
$\text{C}_5\text{H}_8$	Benzene.....	80.2	394.8	87.2	v. p. 138
$\text{C}_5\text{H}_7\text{N}$	Aniline.....	183	434	88.6	(2.5)
$\text{C}_5\text{H}_7\text{N}$	$\alpha$ -Picoline.....	129	380	88.0	(39)*
$\text{C}_5\text{H}_{10}$	Cyclohexene.....	81.6	371.2	85.9	(57)
$\text{C}_5\text{H}_{10}\text{O}$	Mesityl oxide.....	128	359	87.8	(46)*
$\text{C}_5\text{H}_{10}\text{O}_2$	Diethyl oxalate.....	185	283	90.3	(48)*
$\text{C}_5\text{H}_{11}\text{Cl}$	Cyclohexyl chloride.....	142.0	313	89.4	(60)
$\text{C}_5\text{H}_{11}\text{N}$	Capronitrile.....	156	369	83.5	(47)*
$\text{C}_5\text{H}_{12}$	Cyclohexane.....	80.0	358.8	85.4	(57)
$\text{C}_5\text{H}_{12}$	Hexylene.....	0	388.3		(36)*
$\text{C}_5\text{H}_{12}\text{O}$	Cyclohexanol.....	161.1	453	104.5	(60)
$\text{C}_5\text{H}_{12}\text{O}$	Methyl n-butyl ketone....	127	345	86.3	(46)*
$\text{C}_5\text{H}_{12}\text{O}_2$	n-Butyl acetate.....	124.0	309	90.4	(15)
$\text{C}_5\text{H}_{12}\text{O}_2$	Ethyl n-butyrate.....	118.9	312.6	92.6	(57)
$\text{C}_5\text{H}_{12}\text{O}_2$	Ethyl isobutyrate.....	109.2	301.6	91.6	(57)
$\text{C}_5\text{H}_{12}\text{O}_2$	Isoamyl formate.....	123	308	90.3	(15)
$\text{C}_5\text{H}_{12}\text{O}_2$	Isobutyl acetate.....	115.5	308.7	92.3	(57)
$\text{C}_5\text{H}_{12}\text{O}_2$	Methyl n-valerate.....	116	298	87.4	(69)*
$\text{C}_5\text{H}_{12}\text{O}_2$	Methyl isovalerate.....	116	303	90.4	(15)
$\text{C}_5\text{H}_{12}\text{O}_2$	n-Propyl propionate.....	120.6	306.2	90.3	(57)
$\text{C}_5\text{H}_{14}$	n-Hexane.....	0	373		(36)*
		66.9	342.1	86.7	(75)
		68	332	83.8	(57)*
$\text{C}_5\text{H}_{14}\text{O}$	Ethyl isobutyl ether.....	79.0	313	90.8	(60)
$\text{C}_5\text{H}_{14}\text{O}_2$	Acetal.....	102.9	277	87.0	(46)*
$\text{C}_5\text{H}_{15}\text{N}$	Di-n-propylamine.....	108	317	84.2	(39)*
$\text{C}_7\text{H}_5\text{N}$	Benzonitrile.....	189	367	81.9	(38)*
$\text{C}_7\text{H}_5\text{O}$	Benzaldehyde.....	179	362	84.9	(48)*
$\text{C}_7\text{H}_5\text{O}_2$	Salicylaldehyde.....	196	313	81.5	(50)*
$\text{C}_7\text{H}_7\text{Cl}$	$\alpha$ -Chlorotoluene.....	158.1	304	89.2	(57)
$\text{C}_7\text{H}_7\text{Cl}$	p-Chlorotoluene.....	160.4	306.1	89.4	(57)
$\text{C}_7\text{H}_8$	Toluene.....	109.6	362.2	87.2	(57)
$\text{C}_7\text{H}_8\text{O}$	Phenyl methyl ether.....	153	341	86.5	(49)*
$\text{C}_7\text{H}_8\text{O}$	Benzyl alcohol.....	204.3	470	106.4	(57)
$\text{C}_7\text{H}_8\text{O}$	m-Cresol.....	202	421	95.8	(47)*
$\text{C}_7\text{H}_9\text{N}$	Methylaniline.....	194	400	91.7	(49)*
$\text{C}_7\text{H}_9\text{N}$	$\alpha$ -Toluidine.....	198	398	90.5	(49)*
		198	382	86.8	(45)*
$\text{C}_7\text{H}_{14}$	Dimethylcyclopentane....	91	339	91.4	(52)*
$\text{C}_7\text{H}_{14}$	Methylcyclohexane.....	99.9	321.9	84.7	(57)
$\text{C}_7\text{H}_{14}\text{O}$	Dipropylketone.....	143.5	317	86.9	(46)*
$\text{C}_7\text{H}_{14}\text{O}$	Methyl n-amyl ketone....	149.2	346	93.6	(57.2)
$\text{C}_7\text{H}_{14}\text{O}_2$	n-Butyl propionate.....	144.9	300.3	82.0	(57)
$\text{C}_7\text{H}_{14}\text{O}_2$	Isobutyl propionate.....	137	276	76.8	(69)*
$\text{C}_7\text{H}_{14}\text{O}_2$	Ethyl n-valerate.....	98	328	90.3	(69)*
$\text{C}_7\text{H}_{14}\text{O}_2$	Ethyl isovalerate.....	144	284	77.7	(15)
$\text{C}_7\text{H}_{14}\text{O}_2$	Isoamyl acetate.....	143.6	289	79.2	(15)
$\text{C}_7\text{H}_{14}\text{O}_2$	n-Propyl n-butyrate.....	143.6	286	78.3	(15)
$\text{C}_7\text{H}_{14}\text{O}_2$	n-Propyl isobutyrate.....	134	267	74.9	(69)*
$\text{C}_7\text{H}_{16}$	n-Heptane.....	97.5	319.4	86.3	(57)
$\text{C}_7\text{H}_{16}\text{O}$	n-Heptyl alcohol.....	176	439	113.5	(15)
$\text{C}_8\text{H}_8\text{O}$	Acetophenone.....	203.7	323	81.4	(47)*
$\text{C}_8\text{H}_{10}$	Ethylbenzene.....	135.2	339.6	88.3	(57)
$\text{C}_8\text{H}_{10}$	$\alpha$ -Xylene.....	141.4	346.9	88.8	(47)
$\text{C}_8\text{H}_{10}$	m-Xylene.....	138.5	342.6	88.3	(57)
$\text{C}_8\text{H}_{10}$	p-Xylene.....	137.1	339.1	87.7	(57)
$\text{C}_8\text{H}_{11}\text{N}$	Dimethylaniline.....	193	338	87.8	(49)*
$\text{C}_8\text{H}_{16}$	Dimethylcyclohexane....	118.5	300	85.9	(52)*
$\text{C}_8\text{H}_{16}\text{O}$	Methyl hexyl ketone....	173	310	89.1	(48)*
$\text{C}_8\text{H}_{16}\text{O}_2$	Isoamyl propionate.....	161	273	90.7	(15)
$\text{C}_8\text{H}_{16}\text{O}_2$	Isobutyl n-butyrate.....	157	270	90.5	(15)
$\text{C}_8\text{H}_{16}\text{O}_2$	Isobutyl isobutyrate.....	148	265	90.7	(15)
$\text{C}_8\text{H}_{16}\text{O}_2$	n-Propyl isovalerate.....	156	270	90.7	(15)
$\text{C}_8\text{H}_{18}$	4-Methylheptane.....	117.2	296.5	86.7	(57)
$\text{C}_8\text{H}_{18}$	n-Octane.....	125	297	85.2	(52)*
$\text{C}_8\text{H}_{18}\text{O}$	n-Octyl alcohol.....	196	408	113.2	(15)
$\text{C}_8\text{H}_{18}\text{O}$	dl-sec.-Octyl alcohol.....	180	395	113.5	(15)
$\text{C}_8\text{H}_{19}\text{N}$	Diisobutylamine.....	134	275	87.3	(38)*
$\text{C}_8\text{H}_{19}\text{O}_2$	Ethyl benzoate.....	(213)	270	(83.5)	(44)*
$\text{C}_9\text{H}_{12}$	Mesitylene.....	165	311	85.3	(16)
$\text{C}_9\text{H}_{12}$	n-Propylbenzene.....	157	301	84.1	(69)*
$\text{C}_9\text{H}_{12}$	Pseudocumene.....	(169)	308	(83.8)	(45)*
$\text{C}_9\text{H}_{18}\text{O}_2$	Isoamyl n-butyrate.....	169	259	92.7	(16)







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## HEATS OF ADSORPTION AND OF WETTING

H. R. KRUYT AND J. G. MODDERMAN

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## HEAT OF ADSORPTION

## Abbreviations and Units

A Total amount of gas adsorbed per g of adsorbent, expressed in cm<sup>3</sup> reduced to NTP, unless otherwise indicated.

Q Total heat evolved by the adsorption of A, joules.

## Gases on Charcoal

A, cm <sup>3</sup> /g	Q, joule	P, range mm Hg	ΔQ/ΔA
Coconut C, heated to 550°, and out-gassed at 400° (d = 1.86) (14)			
N <sub>2</sub> , 0°C			
0.258	0.356	0-10.7	1.381
2.210	2.122	10.7-91.6	0.904
4.169	3.754	91.6-178.9	0.838
7.237	6.463	178.9-342.2	0.883
10.052	8.934	342.2-524.4	0.879
13.049	11.589	524.4-748.9	0.887
NH <sub>3</sub> , 0°C			
5.407	11.389	0-2.9	2.106
30.157	50.877	2.9-28.8	1.595
60.394	96.430	28.8-78.7	1.507
90.290	140.181	78.7-161.0	1.463
115.725	177.652	161.0-319.2	1.473
127.045	195.332	319.2-490.0	1.565
132.387	203.971	490.0-636.4	1.615
135.873	209.638	636.4-746.7	1.628

A, cm<sup>3</sup>/g | Q, joule | P, range mm Hg | ΔQ/ΔA

Coconut C, heated to 550°, and out-gassed at 400° (d = 1.86) (14)

CO <sub>2</sub> , 0°C			
2.286	3.300	0-2.2	1.443
11.310	15.542	2.2-18.7	1.357
22.556	29.916	18.7-55.1	1.278
33.416	43.539	55.1-122.1	1.254
43.904	56.436	122.1-229.3	1.230
50.850	64.921	229.3-337.7	1.222
56.937	(71.693)	337.7-471.3	(1.114)
61.639	77.345	471.3-605.5	1.199
65.112	81.467	605.5-730.9	1.187

Active coconut C; out-gassed at 350° (11)

CCl <sub>4</sub> , 0°C			
23.56	70.6	0- < < 4	2.99
39.50	111.4	< < 4- < 4	2.56
60.94	174.6	< 4-4	2.95
78.32	215.6	4-10	2.36
CS <sub>2</sub> , 0°C			
23.91	58.3	0- < < 3	2.44
48.40	111.8	< < 3- < 3	2.18
70.02	157.5	< < 3- < 3	2.11
97.94	215.2	< 3-3	2.07
127.67	273.7	3-12	1.97
153.19	321.7	12-40	1.88



## Gases on Charcoal.—(Continued)

A, cm <sup>3</sup> /g	Q, joule	P, range mm Hg	ΔQ/ΔA
Active coconut C, out-gassed at 350° (11)			
CHCl <sub>3</sub> , 0°C			
22.30	62.4	0- < < 7	2.80
45.49	123.1	< < 7- < 7	2.62
78.36	204.4	< 7-7	2.47
107.10	274.2	7	2.43
CH <sub>3</sub> OH, 0°C			
21.67	56.0	0- < < 13	2.59
47.42	115.7	< < 13- < 13	2.32
75.27	179.0	< < 13- < 13	2.27
103.27	240.4	< 13-13	2.19 <sub>3</sub>
127.40	293.3	13-18	2.19 <sub>2</sub>
C <sub>2</sub> H <sub>5</sub> Cl, 0°C			
29.10	67.2	0- < < 15	2.31
42.66	96.3	< < 15- < 15	2.15
67.01	145.6	< < 15- < 15	2.02
102.81	214.3	< 15-15	1.92
124.80	255.4	15-52	1.87
C <sub>2</sub> H <sub>5</sub> Br, 0°C			
48.90	124.9	0- < 10	2.56
91.73	219.9	< 10-10	2.22
120.48	281.0	10-37	2.13
C <sub>2</sub> H <sub>5</sub> I, 0°C			
34.42	90.9	0- < 2	2.64
67.52	173.3	< 2-2	2.49
99.17	251.0	2-5	2.46
124.72	310.2	5-39	2.32
C <sub>2</sub> H <sub>5</sub> OH, 0°C			
4.59	15.15	0	3.30
8.40	26.24		2.91
14.23	42.64		2.81
27.83	79.98		2.75
46.91	129.8		2.61
HCO <sub>2</sub> C <sub>2</sub> H <sub>5</sub> , 0°C			
32.30	91.9	0- < < 10	2.85
62.88	168.5	< < 10- < 10	2.50
96.73	249.8	< 10-10	2.40
120.15	305.5	10-35	2.38
(C <sub>2</sub> H <sub>5</sub> ) <sub>2</sub> O, 0°C			
18.10	56.0	0- < < < 10	3.10
37.68	109.1	< < < 10- < < 10	2.71
58.07	163.5	< < 10- < 10	2.67
86.77	225.1	< 10-10	2.15
99.34	253.7	10-63	2.28
C <sub>6</sub> H <sub>6</sub> , 0°C			
28.37	80.2	0- < 2	2.83
54.70	150.2	< 2-2	2.64 <sub>9</sub>
81.03	219.9	2-3	2.64 <sub>7</sub>
102.04	273.3	3-13	2.54
Inactive coconut C, out-gassed at 350° (11)			
CCl <sub>4</sub> , 0°C			
24.33	68.6	0- < 21	2.82
36.27	94.4	< 21-21	2.16
CH <sub>3</sub> OH, 0°C			
32.65	83.5	0- < 2	2.56
60.95	149.0	< 2-2	2.32
88.35	211.0	2-4	2.26
117.09	274.7	4-14	2.22
C <sub>6</sub> H <sub>6</sub> , 0°C			
18.48	55.9	0- < 4	3.02
36.28	106.5	< 4-4	2.84
47.93	138.8	4-9	2.77

A, cm <sup>3</sup> /g	Q, joule	P, range mm Hg	ΔQ/ΔA
SO <sub>2</sub> on blood C (puriss. Merck) out-gassed at 450°C (d = 1.63 measurements at -10°C (16)			
21.4	41.9	0-1.0	1.09 <sub>6</sub>
54.2	97.3	1.0-3.6	1.69 <sub>1</sub>
87.4	151.3	3.6-9.2	1.62 <sub>6</sub>
123.5	205.2	9.2-16.4	1.49 <sub>2</sub>
159.2	256.7	16.4-(31.1)	1.44 <sub>8</sub>
193.8	304.0	(31.1)-45.0	1.36 <sub>6</sub>
226.5	353.4	45.0-(71.8)	1.51 <sub>0</sub>
256.8	398.3	(71.8)-(103.2)	1.48 <sub>3</sub>
283.2	437.2	(103.2)-136.4	1.47 <sub>2</sub>
323.4	493.9	136.4-(246.3)	1.41 <sub>1</sub>
352.1	533.3	(246.3)-397.3	1.37 <sub>1</sub>
369.7	556.4	397.3-533.0	1.31 <sub>6</sub>
386.4	575.2	533.0-(653.2)	1.12 <sub>5</sub>
409.9	600.4	(653.2)-720.5	1.07 <sub>3</sub>
439.9	631.6	720.5-755.0	1.03 <sub>9</sub>
466.3	659.5	755.0-764.0	1.05 <sub>9</sub>

C from the wood of *Evonymus europaeus*, out-gassed at red heat (3)

Air, 0°C			
7.44	3.37	0-705	0.45 <sub>3</sub>
CH <sub>3</sub> Cl, 0°C			
32.17	65.47	0-3.77	2.03 <sub>5</sub>
62.16	124.5	3.77-147.81	1.96 <sub>8</sub>
72.31	144.8	147.81-675.4	1.99 <sub>7</sub>

Active C de-ashed and out-gassed at 900°C (8)

O <sub>2</sub> , 0°C			
0.403	5.23		12.9 <sub>8</sub>
0.806	8.87		9.0 <sub>8</sub>
2.24	12.56		2.57
5.17	15.48		1.00
10.19	19.96		0.89
H <sub>2</sub> O, 0°C*			
0.921	32.89		35.7
2.710	112.37		44.4
4.56	194.27		44.3
6.42	275.71		43.8
Cl <sub>2</sub> , 0°C			
0.31	1.80		5.81
0.74	3.77		4.5 <sub>8</sub>
5.52	27.79		5.0 <sub>2</sub>
NH <sub>3</sub> , 0°C			
3.70	9.37		2.5 <sub>3</sub>
14.92	26.11		1.51
24.75	40.93		1.51
34.45	55.03		1.4 <sub>6</sub>
CO <sub>2</sub> , 0°C			
3.80	5.69		1.50
12.04	16.15		1.27
31.06	40.47		1.2 <sub>8</sub>
(C <sub>2</sub> H <sub>5</sub> ) <sub>2</sub> O, 0°C			
6.92	21.93		3.17
14.04	42.39		2.87
22.21	63.15		2.54
29.93	82.48		2.50
37.04	94.41		1.6 <sub>8</sub>
47.36	107.6		1.2 <sub>8</sub>
CCl <sub>3</sub> NO <sub>2</sub> , Chloropicrin, 0°C*			
0.307	20.84		67.9
0.672	42.48		59.3
1.012	59.89		51.2

\* A in millimoles per gram.



A, cm <sup>3</sup> /g	Q, joule	P, range mm Hg	$\Delta Q/\Delta A$
Activated C dried at 150° and out-gassed at 100° (15)			
O <sub>2</sub> , 0°C			
4.39	3.22	0-370	0.733
8.54	6.13	370-802	0.702
CO, 0°C			
4.84	4.01	0-233.1	0.83
9.40	7.60	233.1-540.1	0.79
CH <sub>4</sub> , 0°; P corr. for N <sub>2</sub> (10%) present			
4.71	4.61	0-63.0	0.98
9.23	8.95	63.0-169.2	0.96
13.57	12.81	169.2-320.3	0.89
17.72	16.27	320.3-517.0	0.83

O<sub>2</sub> on "Norit" out-gassed at 900°C (2)

°C	A	Q	P, range	Q/A
15	0.216	2.59	0-	12.0
200†	0.302	6.43	0-2	21.3
310	0.158	5.07	0-2.7	32.1
450	0.133	5.55	0-3.4	41.7

† Above 200° CO<sub>2</sub> is formed and a correction has been applied for this heat of reaction.Various gases on coconut C at -185°C; A is cm<sup>3</sup> of gas adsorbed per cm<sup>3</sup> (0.5-1 g) of charcoal from 0 to ca. 760 mm (4)

Gas	A	Q	Q/A
A.....	175	104.6	0.598
He.....	15	8.37	0.558
O <sub>2</sub> .....	230	142.3	0.619
H <sub>2</sub> .....	135	38.9	0.288
N <sub>2</sub> .....	155	106.7	0.688
CO.....	190	115.1	0.606
2H <sub>2</sub> + Q <sub>2</sub> .....	150	71.1	0.474
2CO + O <sub>2</sub> .....	195	144.4	0.740

Gases on various kinds of charcoal at room temperature and from 0 to ca. 760 mm; A and Q vary with the nature of the charcoal but the ratio is approx. constant (5)

Gas	HCl	HBr	HI	N <sub>2</sub> O
Q/A	0.429	0.692	0.984	0.332

## Gases on Metals

H<sub>2</sub> on Ni catalysts at 0° (7)

A, cm <sup>3</sup>	Q	$\Delta Q/\Delta A$
Catalyst I. Prepared by heating NiCO <sub>3</sub> at 300-320° for 120 hr and out-gassing at 300°; adsorbs 0.9 cm <sup>3</sup> H <sub>2</sub> per g at NTP		
0.0396	0.1895	4.77
0.0772	0.3086	3.18
0.114	0.4184	2.98
0.180	0.5949	2.68
0.260	0.7936	2.49
0.795	2.0296	2.34
Catalyst II. Reduced for 60 hr; contained 13.5% ThO <sub>2</sub> ; adsorbs 0.72 cm <sup>3</sup> H <sub>2</sub> per g at NTP		
0.0315	0.0804	2.56
0.0612	0.2325	5.11
0.0918	0.4187	6.08
0.1211	0.5832	5.57
0.2082	1.0148	4.95
0.2453	1.1646	4.01
0.332	1.3581	2.23
0.722	2.1938	2.14

CO<sub>2</sub> on Ni catalyst at 0° (7)

Catalyst III. Reduced from the oxide for 260 hr at 300-320°; contained 4% Ce <sub>2</sub> O <sub>3</sub>		
0.082	0.271	3.29
0.619	1.04	1.48
0.874	1.24	0.789

H<sub>2</sub> on Ni and Cu at room temperature. The H<sub>2</sub> contained an unknown but negligible amount of N<sub>2</sub> (1)

A, cm <sup>3</sup>	Q	P, range	$\Delta Q/\Delta A$
On Ni reduced from NiO at 300°; results are greatly affected by previous treatment of the Ni			
0.403	0.998	0-2.7	2.48
0.865	2.086	2.7-8.7	2.35
1.123	2.792	8.7-703.4	2.73
On Cu reduced from CuO by H <sub>2</sub> at 145°			
0.438	0.786	0-760	1.793

Gases on Ni at 0° and from 0 to 760 mm (6)

Out-gassed at t, °C	A	Q	Q/A
304	5.2	15.70	3.03
240	3.7	10.98	2.97
196	2.9	8.56	2.95
145	2.1	5.49	2.61
120	1.8	4.28	2.38
90	1.5	3.22	2.15
0	0.54	1.16	2.15

Gas	A	Q	Q/A
C <sub>2</sub> H <sub>4</sub> .....	0.88	1.04	1.18
C <sub>2</sub> H <sub>6</sub> .....	0.75	0.78	1.05

H<sub>2</sub> and O<sub>2</sub> on Pt-black at 0° and from 0 to 760 mm (12); for H<sub>2</sub> on Pt-black carefully freed from O<sub>2</sub>, A = 0.87 cm<sup>3</sup> and  $\Delta Q/\Delta A = 2.58$ ; for O<sub>2</sub> the values of Q/A vary from 6 to 18 joule/cm<sup>3</sup>. The authors consider 6.6 as the best value.Gases on SiO<sub>2</sub> and on Meerschaum

On meerschaum (d = 2.76) (3)

A	Q	P, range	$\Delta Q/\Delta A$
SO <sub>2</sub> , 0°			
24.24	46.82	0-98.9	1.932
46.14	74.13	98.9-377.1	1.247
67.75	96.99	377.1-687.4	1.058
NH <sub>3</sub> , 0°			
24.23	92.95	0-0	3.84
48.26	150.07	0-5	2.38
72.29	201.11	5-37.1	2.12
95.26	239.64	29.3-214.96	1.68
116.74	270.22	214.96-575.6	1.42
CH <sub>3</sub> Cl, 0°			
20.96	41.07	0-34.9	1.959
39.59	66.78	34.9-484.9	1.380
41.72	69.67	484.9-561.9	1.355

On SiO<sub>2</sub> gel dried at 300° for 2 hr and out-gassed at 250°; contained 3.5-5.5% H<sub>2</sub>O (13)

A	Q	P, range	$\Delta Q/\Delta A$
SO <sub>2</sub> , 0°			
19.80	41.85	0-4.2	2.113
32.42	64.87	4.2-11.8	1.824
56.43	108.0	11.8-40.1	1.796
80.71	145.6	40.1-102.5	1.549
123.1	211.8	102.5-388.8	1.562
142.3	233.5	388.8-611.2	1.130
H <sub>2</sub> O on the same gel, 0°; A in millimoles			
1.826	113.0	0-0.3	61.88
6.361	349.0	0.3-0.8	52.04
12.85	657.0	0.8-2.1	47.46
15.35	771.7	2.1-3.4	45.88
19.94	975.1	3.4-4.6	44.31



## From Aqueous Solutions

Crystal violet on wetted blood charcoal (Merck) at room temp.;  
A in millimoles (9)

A	Q	$\Delta Q/\Delta A$
0.31	13.42	43.3
0.42	14.03	5.55

Salts on wetted blood charcoal (Merck) at room temp.; A in millimoles (10)

Salt	A	Q	Q/A
On Charcoal I. Heat of wetting = 25.11 J			
LiNO <sub>3</sub>	0.214	5.36	25.0
NaNO <sub>3</sub>	0.270	7.11	26.4
CsNO <sub>3</sub>	0.354	12.05	34.1
On Charcoal II. Heat of wetting = 35.15 J			
LiNO <sub>3</sub>	0.202	7.53	37.2
KNO <sub>3</sub>	0.248	10.80	43.5
CsNO <sub>3</sub>	0.336	16.49	49.0

## LITERATURE

(For a key to the periodicals see end of volume)

- (1) Beebe and Taylor, 1, 46: 43; 24. (2) Blench and Garner, 4, 125: 1288; 24.  
(3) Chappuis, 8, 19: 21; 83. (4) Dewar, 5, 74: 122; 04. 6, 3: 5; 04. (5) Favre, 6, 1: 209; 74. (6) Foresti, 36, 53: 487; 23. 54: 132; 24. 55: 185; 25. (7) Fryling, 50, 30: 818; 26. (8) Keyes and Marshall, 1, 49: 156; 27.  
(9) Kruyt and van der Spek, 55, 24: 145; 19.  
(10) Lachs and Lachman, 7, 123: 303; 26. (11) Lamb and Coolidge, 1, 42: 1146; 20. (12) Mond, Ramsay and Shields, 7, 25: 657; 98. (13) Patrick and Greider, 50, 29: 1031; 25. (14) Titov, 7, 74: 641; 10. (15) Whitehouse, 54, 45: 13T; 26. (16) Williams, 68, 37: 161; 16.

## HEAT OF WETTING

Except as otherwise indicated the values given represent heat of complete wetting, Q, in joules per g of the dry material.

Index.—The numbers are table numbers except those in ( ) which are literature references (v. p. 143).

Liquid	Fibers	Soils	Colloids	PbSO <sub>4</sub>
H <sub>2</sub> O	6 (12, 20, 28, 34)	(1, 6, 7, 8, 9, 10, 11, 15, 26, 30, 35)	10, 11	18

	Char-coal	SiO <sub>2</sub>	Clays and earths	Starch, cellulose, etc.
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H <sub>2</sub> O	1, 2, 6, 12 to 16	1, 3, 4, 5, 6, 11, 12	1, 2, 11, 13	1, 6, 8, 9
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CS <sub>2</sub> , Carbon disulfide	1, 2, 15	1	1, 2	1
CCl <sub>4</sub> , Carbon tetrachloride	1, 2	1, 3	1, 2	1

C <sub>2</sub> Cl <sub>4</sub> , Tetrachloroacetylene	15			
CHCl <sub>3</sub> , Chloroform	1, 2	1, 7	1, 2	1

## Hydrocarbons

C <sub>5</sub> H <sub>10</sub> , Amylene			2	
C <sub>5</sub> H <sub>12</sub> , Pentane	1	1	1	1
C <sub>6</sub> H <sub>6</sub> , Benzene	1, 2, 15, 16	1, 3, 4	1, 2	1

C <sub>6</sub> H <sub>10</sub> , Cyclohexene			2	
C <sub>6</sub> H <sub>12</sub> , Hexamethylene	2		2	
C <sub>6</sub> H <sub>14</sub> , Hexane	1, 2	1	1, 2	1

C <sub>7</sub> H <sub>8</sub> , Toluene		4, 7		
C <sub>10</sub> H <sub>16</sub> , Pinene	2		2	

## Alcohols

CH <sub>3</sub> OH, Methyl	1, 2, 15	1	1, 2	1
C <sub>2</sub> H <sub>5</sub> OH, Ethyl	1, 2, 15	1, 3	1, 2	1
C <sub>3</sub> H <sub>7</sub> OH, Propyl	1	1	1	1
C <sub>4</sub> H <sub>9</sub> OH, Amyl	1, 2	1, 7	1, 2	1
C <sub>6</sub> H <sub>5</sub> CH <sub>2</sub> OH, Benzyl	1	1	1	1

Liquid	Char-coal	SiO <sub>2</sub>	Clays	Starch
Ethers, esters, ketones, acids				
C <sub>3</sub> H <sub>8</sub> O, Acetone	1, 2	1	1, 2	1
C <sub>4</sub> H <sub>8</sub> O <sub>2</sub> , Ethyl acetate	2		2	
C <sub>4</sub> H <sub>10</sub> O, Ether	1, 15	1, 7	1, 2	1
Fatty acids	1	1	1	1
Naphthenic acids			2	
N compounds				
C <sub>5</sub> H <sub>5</sub> N, Pyridine		4, 7		
C <sub>6</sub> H <sub>5</sub> NH <sub>2</sub> , Aniline		3	2	
C <sub>6</sub> H <sub>5</sub> NO <sub>2</sub> , Nitrobenzene		4		
Miscellaneous				
Petroleum products	2		2	
Vegetable oils				

Cu

17

17

TABLE 1.—POWDERS DRIED AT 100°

Experiments at 12–13° (14)

Liquid	Clay	Amorph. silica	Starch	Sugar charcoal
H <sub>2</sub> O	52.7	64.0	85.4	16.3
CH <sub>3</sub> OH	46.0	64.0	23.4	48.1
C <sub>2</sub> H <sub>5</sub> OH	45.2	61.5	20.5	28.9
C <sub>3</sub> H <sub>7</sub> OH	42.7	56.5	29.3	23.4
C <sub>4</sub> H <sub>9</sub> OH	42.3	56.5	13.0	15.5
C <sub>6</sub> H <sub>5</sub> CH <sub>2</sub> OH	38.9	56.5	17.6	15.5
HCOOH	50.2	60.7	33.5–41.8	50.2 ±
CH <sub>3</sub> COOH	38.9	56.5	12.6–16.7	25.1
C <sub>2</sub> H <sub>5</sub> COOH	32.6	56.5	12.6–16.7	25.1
CH <sub>3</sub> COCH <sub>3</sub>	33.5	56.5	8.4	15.1
CHCl <sub>3</sub>	37.7	33.5	8.4	9.6
C <sub>2</sub> H <sub>5</sub> OC <sub>2</sub> H <sub>5</sub>	24.3	35.2	9.2	5.0
C <sub>6</sub> H <sub>6</sub>	24.3	33.9	5.0	17.6
CCl <sub>4</sub>	7.5	33.9	7.1	6.3
CS <sub>2</sub>	7.1	15.1	2.1	16.7
C <sub>6</sub> H <sub>5</sub> —C <sub>6</sub> H <sub>5</sub>	5.0	13.0	1.26	1.67

TABLE 2 (17)

Liquid	Clay	"Floridin"	Bone charcoal
Amylene	329.8	239.0	
H <sub>2</sub> O		126.0	77.4
Cyclohexene		117.6	
CH <sub>3</sub> COCH <sub>3</sub>		114.2	80.8
Pinene	86.2		72.0
CH <sub>3</sub> OH	115.5	91.2	73.7
CH <sub>3</sub> CO <sub>2</sub> C <sub>2</sub> H <sub>5</sub>		77.4	69.1
C <sub>2</sub> H <sub>5</sub> OH	102.5	72.0	69.1
C <sub>6</sub> H <sub>5</sub> NH <sub>2</sub>		56.1	
C <sub>6</sub> H <sub>11</sub> OH	85.4	45.6	44.4
C <sub>2</sub> H <sub>5</sub> OC <sub>2</sub> H <sub>5</sub>		43.9	
CHCl <sub>3</sub>	65.7	35.2	58.6
C <sub>6</sub> H <sub>6</sub>	45.2	23.4	46.5
CCl <sub>4</sub>	41.4	19.3	35.2
CS <sub>2</sub>	39.3	17.6	58.2
Hexamethylene		17.6	38.5
C <sub>6</sub> H <sub>14</sub>	30.1	16.3	37.2
Petroleum fractions*	B. P., 220–225°	22.2	56.1
	B. P., 150–155°	18.8	49.4
Gasoline, B. P., 80–85°		17.6	39.8
Naphthenic acids†	Mol. wt., 405	59.4	
	Mol. wt., 298	56.5	
	Mol. wt., 221	53.6	

\* Treated with fuming H<sub>2</sub>SO<sub>4</sub> to remove unsaturated and aromatic hydrocarbons. † Diluted with 20 vol. % of gasoline to decrease viscosity.



TABLE 3 (31)		TABLE 4.—SiO <sub>2</sub> OUT-GASSED AT RED HEAT (25)		
Liquid	SiO <sub>2</sub> gel	Liquid	Mean diam., cm	
			$5 \times 10^{-4}$	$9.6 \times 10^{-4}$
H <sub>2</sub> O.....	80.4	H <sub>2</sub> O.....	57.8	28.9
C <sub>2</sub> H <sub>5</sub> OH.....	94.7	C <sub>6</sub> H <sub>5</sub> NO <sub>2</sub> .....	46.2	26.2
C <sub>6</sub> H <sub>6</sub> .....	46.6	C <sub>6</sub> H <sub>5</sub> CH <sub>3</sub> .....	35.6	20.3
CCl <sub>4</sub> .....	35.2	C <sub>6</sub> H <sub>5</sub> .....	17.1	17.1
C <sub>6</sub> H <sub>5</sub> NH <sub>2</sub> .....	73.4	C <sub>6</sub> H <sub>5</sub> N.....	50.8	20.8

TABLE 5.—SiO<sub>2</sub> WITH H<sub>2</sub>O (29)

Specimen SiO <sub>2</sub>	Q at 7°	Diam., cm $\times 10^{-4}$	Joule/m <sup>2</sup>
SiO <sub>2</sub> (glass wool).....	3.85	17.5	46.0
SiO <sub>2</sub> (fine gray sand).....	0.96	100.	41.8
SiO <sub>2</sub> I (precipitated).....	47.3	2.5	43.5
SiO <sub>2</sub> II (precipitated).....	30.1	4.0	43.9
SiO <sub>2</sub> II (precipitated).....	31.6 (Q at 24°)		

Heat of Complete Wetting per g Dry Material (Q<sub>i</sub>)

Powders containing varying initial amounts of hygroscopic moisture,  $i$  = mg H<sub>2</sub>O per g dry powder.

TABLE 6.—WITH H<sub>2</sub>O

Powder	$i$	Q <sub>i</sub>	$i$	Q <sub>i</sub>
Cellulose (22, 23); dried <i>in vacuo</i> at 116°	14	33.90	74	10.89
	41	19.67	261	4.61
	54	16.74		
Animal charcoal at 0° (22, 23)	0	87.51	563	13.06
	49	73.91	659	6.66
	90	64.20	718	4.56
	218	49.34	753	1.21
	350	33.07	930	0
	437	25.32		
SiO <sub>2</sub> gel at 0° (4)	23	77.59	275	22.57
	57	50.93	399	15.48
	87	38.50	565	6.95
	129	32.14	769	0.80
	188	27.20		
Wood fiber (12)	?	67		

TABLE 7.—SiO<sub>2</sub> GEL WITH VARIOUS LIQUIDS (4)

Liquids	$i$	Q <sub>i</sub>	Liquids	$i$	Q <sub>i</sub>
C <sub>6</sub> H <sub>5</sub> CH <sub>3</sub> .....	23	32.73	C <sub>6</sub> H <sub>5</sub> OH.....	17	51.35
CHCl <sub>3</sub> .....	13	32.52	C <sub>2</sub> H <sub>5</sub> OC <sub>2</sub> H <sub>5</sub> .....	31	68.59
C <sub>6</sub> H <sub>5</sub> N.....	18	60.05	C <sub>2</sub> H <sub>5</sub> OC <sub>2</sub> H <sub>5</sub> .....	276	37.04
C <sub>6</sub> H <sub>5</sub> OH.....	27	55.87			

TABLE 8.—STARCH WITH H<sub>2</sub>O AT 0° (HEAT OF SWELLING)  
The starch has been dried for 21 days in partial vacuum above H<sub>2</sub>SO<sub>4</sub>, Q = 110.5 joule/g (32).

TABLE 9.—DEXTRIN WITH H<sub>2</sub>O

Q = 67.6 joule/g (33).

TABLE 10.—HEAT OF SWELLING AND OF SOLUTION, PER G MATERIAL (36)

Material	Amount	+H <sub>2</sub> O	Q
Gelatin			
	$t = 42.5^\circ$ .....	1 g	5 g
	$t = 42.5^\circ$ .....	1 g + 100% H <sub>2</sub> O	4 g
	$t = 34.3^\circ$ .....	1 g + 200% H <sub>2</sub> O	3 g
	$t = 25^\circ$ .....	1 g + 300% H <sub>2</sub> O	2 g
Gum arabic.....	1 g	5 g	+37.6
	1 g + 50% H <sub>2</sub> O	2 g	- 2.5
Gum tragacanth.....	1 g	5 g	+43.1

TABLE 11.—COLLOIDS WITH H<sub>2</sub>O (9)

Colloid	Q	Colloid	Q
Al(OH) <sub>3</sub> .....	89.6	Silica gel.....	101.5
Fe(OH) <sub>3</sub> .....	39.3	Fuller's earth.....	88.9
Quartz.....	1.88		

TABLE 12.—SILICA AND ANIMAL CHARCOAL, WITH WATER (13)

	Q
Silica (dried at 200°).....	55.41
Charcoal (puriss.).....	59.55

TABLE 13.—WITH H<sub>2</sub>O (18, 19)

Coconut charcoal (out-gassed).....	43.9	Bone charcoal....	77.4
Coconut charcoal (containing 0.04 g H <sub>2</sub> O).....	14.6	Fuller's earth....	134

TABLE 14.—WITH H<sub>2</sub>OGraphite preheated *in vacuo*. Q = 2.85 joule/g (27).

TABLE 15.—"BAYER" CHARCOAL AT ROOM TEMPERATURE (2)

Liquid	Q	Liquid	Q
C <sub>2</sub> H <sub>5</sub> OC <sub>2</sub> H <sub>5</sub> .....	118.4	CH <sub>3</sub> OH.....	126.4
C <sub>6</sub> H <sub>6</sub> .....	123.0	C <sub>2</sub> Cl <sub>4</sub> .....	137.3
CS <sub>2</sub> .....	125.6	H <sub>2</sub> O.....	51.5*
C <sub>2</sub> H <sub>5</sub> OH.....	118.9		

\* With 0.66 cm<sup>3</sup> H<sub>2</sub>O per g. Possibly incomplete wetting.TABLE 16.—VARIOUS CHARCOALS WITH H<sub>2</sub>O AND C<sub>6</sub>H<sub>6</sub>

The activity,  $a$ , is taken as proportional to the adsorptive power for H<sub>2</sub> (21).  $d$  is approximate.

$a$	$d$	H <sub>2</sub> O	C <sub>6</sub> H <sub>6</sub>	$a$	$d$	H <sub>2</sub> O	C <sub>6</sub> H <sub>6</sub>
10		20.9	25.1	75	1.87	154.8	209.0
20		41.8	54.4	90		188.3	251.1
25	1.45	50.2	71.1	98	2.00	205.1	272.0
50		104.6	138.1	100		209.0	280.4

TABLE 17.—CU WITH OILS

All samples (except kerosene) diluted 1:2 with C<sub>6</sub>H<sub>6</sub>; Q for C<sub>6</sub>H<sub>6</sub> taken as 0 (3)

Oil	Q	Oil	Q
Castor oil.....	0.51	Paraffin oil.....	0.16
Linseed oil.....	0.58	Kerosene.....	0.24
Lubricating oil, distillate	0.60	Kerosene + 1% oleic acid.....	0.89
Lubricating oil, refined..	0.26		

For temperature rise on wetting charcoal with oils,  $v$ . (3-5).TABLE 18.—PbSO<sub>4</sub> WITH ITS SATURATED AQUEOUS SOLUTION  
For total surface of 5840 to 32 400 cm<sup>2</sup>/g, Q = 0 (24).

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# THERMAL EFFECTS ACCOMPANYING PRESSURE CHANGES IN HOMOGENEOUS SYSTEMS (JOULE-THOMSON AND RELATED EFFECTS)

J. R. ROEBUCK

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$$\text{JOULE-THOMSON EFFECT } \mu = \left( \frac{\partial T}{\partial P} \right)_h, h = U + p\bar{v}$$

A-TABLE, ELEMENTARY SUBSTANCES AND ATMOSPHERIC AIR

Values of $\mu$ in °C/atm. (11)								Air, values of $10^3\mu$ , unit, °C/atm. (20); cf. (9)							
°C	0	20	40	60	80	100		p, atm.	0°	50°	100°	150°	200°	250°	280°C
H <sub>2</sub> .....	-0.013	0.018	0.023	0.028	0.033	-0.039		1	266	189	133	93	62.5	40.2	29.7
He.....	v. (17)							20	249	178	124	86	56.4	34.6	24.6
N <sub>2</sub> .....	+0.333	0.291	0.250	0.215	0.187	+0.159		60	214	153	106	71	44.7	25.1	16.1
O <sub>2</sub> .....	+0.366	0.328	0.289	0.255	0.224	+0.193		100	178	128	89	59	34.7	16.4	7.8
Air, values of $10^3a$ and $10^3b$ in the equation, $\mu = a - bp$ , for $p$ in kg/cm <sup>2</sup> , and $\mu$ in °C/kg cm <sup>-2</sup> (14)								140	145	105	72	46.7	25.8	9.3	+1.1
°C	-55	-34	-0.6	+49.2	99.5	149.7	199.3	180	113	83	58	36.6	18.5	+2.7	-5.4
$10^3a$	448	375	272	197	138	84	52	220	81	63	45	28.6	12.7	-2.0	-11.0
$10^3b$	176	129	81	56	36	18	13								

Air, values of  $10^3\mu$ , unit, °C/atm. (25)

°C										°C									
p, atm.	-25	-50	-75	-100	-110	-120	-130	-140	-150	p, atm.	-25	-50	-75	-100	-110	-120	-130	-140	-150
1	317	378	462	576	637	710	807	936	1100	120	187	214	242	203	158	102	57	28	+11
20	297	358	442	562	627	710	819	967	1200	140	164	172	192	142	108	69	38	17	0
40	276	336	417	534	598	577	776	245	52	160	143	155	147	103	76	47	+22	+3	-12
60	255	309	378	472	541	527	362	106	40	180	125	130	116	75	52	28	8	-8	-22
80	232	275	335	386	367	299	141	67	34	200	108	110	82	48	29	+13	-3	-17	-29
100	211	248	288	284	242	158	87	43	21	220	93	91	69	31	+14	-2	-15	-28	-42

Air, values of  $\mu$  in °K/atm. (8)

p, atm.	p, kg/cm <sup>2</sup>	90°	120°	132.6°*	150°	180°	210°	240°	270°	300°K
0	0	2.045	1.265	1.046	0.833	0.602	0.459	0.361	0.285	0.227
25	25.84	-0.005	0.059	1.065	0.847	0.619	0.458	0.345	0.266	0.212
37.17†	38.40	-0.010	0.028	0.723	0.787	0.599	0.443	0.332	0.254	0.204
50	51.67	-0.014	0.013	0.136	0.641	0.555	0.420	0.315	0.244	0.195
75	77.50	-0.020	0.000	0.036	0.266	0.436	0.362	0.282	0.221	0.178
100	103.33	-0.026	-0.010	0.010	0.130	0.299	0.295	0.247	0.196	0.159
125	129.18	-0.031	-0.020	-0.005	0.062	0.203	0.233	0.211	0.172	0.142
150	155.00	-0.035	-0.026		0.025	0.135	0.182	0.175	0.148	0.124
175	180.83	-0.038	-0.032		0.000	0.079	0.130	0.139	0.124	0.106
200	206.7	-0.041	-0.036		-0.017	0.029	0.080	0.101	0.099	0.089

\* Critical temperature. † Critical pressure.

B-TABLE, CHEMICAL COMPOUNDS

CO<sub>2</sub>, unit, °C/atm. (2)

Temp., °K	Pressure in atmospheres								
	0	1	10	20	40	60	72.9	80	100
Vapor phase above line									
400.0	0.6475	0.6440	0.6210	0.5950	0.5375	0.4790	0.4410	0.4225	0.3635
390.0	0.6755	0.6725	0.6485	0.6200	0.5595	0.4965	0.4560	0.3850	0.3235
380.0	0.7080	0.7045	0.6780	0.6475	0.5835	0.5165	0.4742	0.4505	0.3855
370.0	0.7415	0.7335	0.7100	0.6775	0.6160	0.5405	0.4952	0.4705	0.3995
360.0	0.7790	0.7750	0.7455	0.7110	0.6420	0.5685	0.5200	0.4930	0.4155
350.0	0.8195	0.8150	0.7850	0.7500	0.6780	0.6020	0.5500	0.5210	0.4340



CO<sub>2</sub>—(Continued)

Pressure in atmospheres

Temp., °K	0	1	10	20	40	60	72.9	80	100
340.0	0.8640	0.8595	0.8290	0.7950	0.7205	0.5425	0.5872	0.5550	0.4500
330.0	0.9140	0.9095	0.8795	0.8450	0.7720	0.6925	0.6331	0.5945	0.4490
325.0	0.9425	0.9375	0.9075	0.8745	0.8025	0.7230	0.6605	0.6165	0.4220
320.0	0.9710	0.9665	0.9380	0.9050	0.8360	0.7570	0.6900	0.6380	0.3570
315.0	1.0020	0.9985	0.9705	0.9395	0.8735	0.7970	0.7223	0.6500	0.2210
310.0	1.0360	1.0320	1.0055	0.9765	0.9160	0.8435	0.7554	0.6100	0.1585
305.0	1.0710	1.0675	1.0445	1.0155	0.9640	0.9000	0.7468	0.2690	0.1270
304.1	1.0775	1.0740	1.0505	1.0240	0.9735	0.9100	0.6050	0.2420	0.1215
300.0	1.1070	1.1045	1.0840	1.0600	1.0175	0.9675	0.2147	0.1650	0.1005
295.0	1.1480	1.1455	1.1270	1.1090	1.0805	0.1990	0.1324	0.1134	0.0794
290.0	1.1920	1.1900	1.1750	1.1635	1.1525	0.1156	0.9999	0.0815	0.0619
285.0	1.2395	1.2385	1.2280	1.2245	1.2400	0.0761	0.06355	0.0586	0.0478
280.0	1.2900	1.2900	1.2845	1.2915	1.3470	0.0515	0.0454	0.0425	0.0364
275.0	1.3455	1.3455	1.3470	1.3645	0.0414	0.0355	0.0324	0.0309	0.0275
270.0	1.4050	1.4060	1.4155	1.4455	0.0274	0.0246	0.0228	0.0221	0.0202
260.0	1.5375	1.5405	1.5735	1.6375	0.0106	0.0101	0.00973	0.0096	0.0090
250.0	1.6885	1.6954	1.7570	0.0,735	0.0,733	0.0,731	0.0,730	0.0,729	0.0,727
240.0	1.860	1.870	1.974	-0.00723	-0.00742	-0.00761	-0.00774	-0.00781	-0.00801
230.0	2.060	2.070	-0.0168	-0.0171	-0.0177	-0.0183	-0.0187	-0.0190	-0.0195
220.0	2.2855	2.3035	-0.0294	-0.0304	-0.0323	-0.0341	-0.0353	-0.0359	-0.0375

Liquid phase below line

 Supplementary values at graphically determined intersections of isotherms and isobars of  $\mu$  with the saturation curve

	1	5	10	15	20	30	40	50	60	65	70	72.9
$p$ .....	(193.5)	216.2	233.4	245.05	254.1	268.15	279.0	288.0	295.7	299.15	302.35	304.1
$T$ .....	(3.055)	2.510	2.135	1.922	1.773	1.545	1.371	1.211	1.043	0.937	0.801	0.6050
$\mu_v$ .....	(?)	-0.0346	-0.0083	-0.0031	+0.0046	0.0245	0.0575	0.1182	0.2225	0.2985	0.418	0.6050
$\mu_l$ .....												
$T$ .....	216.9	220.0	230.0	240.0	250.0	260.0	270.0	280.0	285.0	290.0	295.0	300.0
$p$ .....	5.15	5.95	8.8	12.65	17.6	23.9	31.55	41.0	41.0	52.55	59.0	61.3
$\mu_v$ .....	2.475	2.410	2.200	2.020	1.841	1.675	1.515	1.354	1.354	1.174	0.961	0.914
$\mu_l$ .....	-0.3375	-0.0290	-0.0167	-0.0074	+0.0007	0.0115	0.0285	0.0625	0.0938	0.1386	0.2095	0.3235

 Values below correspond to regions of rapid rates of change of  $\mu$  along isotherms

$T$ .....	220.0	230.0	304.1	304.1	304.1	304.1	304.1	310.0	310.0	315.0	315.0	315.0
$p$ .....	5.0	5.0	70.0	72.0	74.0	76.0	90.0	85.0	90.0	85.0	90.0	95.0
$\mu$ .....	2.387	2.132	0.822	0.767	0.382	0.310	0.159	0.360	0.250	0.569	0.443	0.312

 $\mu$  as a function of  $p$  along isenthalpic (or total heat) curves

 Pressures in atmospheres; temperatures in °K;  $\mu$  in °K per atm.

$p$	0	1	20	40	60	72.9	80	100
Vapor isenthalps								
$T$ .....	379.94	380.63	393.12	404.56	414.39	420.00	422.88	430.22
$\mu$ .....	0.7080	0.7029	0.6118	0.5284	0.4564	0.4154	0.3944	0.3407
$T$ .....	356.30	357.10	370.92	383.40	394.00	400.00	403.05	410.74
$\mu$ .....	0.7924	0.7860	0.6748	0.5745	0.4892	0.4410	0.4165	0.3546
$T$ .....	331.40	332.30	347.99	361.90	373.52	380.00	383.27	391.43
$\mu$ .....	0.9054	0.8974	0.6582	0.6348	0.5317	0.4742	0.4452	0.3728
$T$ .....	304.30	305.35	323.77	339.76	352.85	360.00	363.57	372.35
$\mu$ .....	1.0760	1.0655	0.8816	0.7220	0.5914	0.5200	0.4844	0.3967
$T$ .....	272.42	273.88	297.03	316.46	331.83	340.00	344.00	353.64
$\mu$ .....	1.3750	1.3590	1.0885	0.8620	0.6826	0.5872	0.5405	0.4280
$T$ .....	226.91	229.09	263.56	290.42	310.15	320.00	324.63	335.27
$\mu$ .....	2.1272	2.0948	1.5620	1.1470	0.8422	0.6900	0.6184	0.4540
$T$ .....	208.69	211.26	[252.26]	282.91	304.56	315.00	319.82	330.59
$\mu$ .....	2.5786	2.5338	[1.8181]	1.2826	0.9046	0.7223	0.6381	0.4501



CO<sub>2</sub>—(Continued)

<i>p</i>	0	1	20	40	60	72.9	80	100
<i>T</i> .....	181.28	[184.70	237.43	274.42]	298.85	310.00	314.97	325.60
<i>μ</i> .....	3.4295	[3.3588	2.2620	1.4928]	0.9850	0.7533	0.6500	0.4290
<i>T</i> .....	157.40	[161.24	226.49	269.35	295.97]	307.50	312.48	322.77
<i>μ</i> .....	4.343	[4.2514	2.6950	1.6727	1.0380]	0.7630	0.6442	0.3998
<i>T</i> .....	120.90	[126.80	212.44	264.32	293.71]	305.50	310.36	319.77
<i>μ</i> .....	6.000	[5.832	3.400	1.926	1.091 ]	0.7560	0.6179	0.3508
<i>T</i> .....	76.00	[ 81.40	198.40	260.85	292.77]	304.50	309.09	317.42
<i>μ</i> .....	8.396	[8.114	4.288	2.1915	1.1200]	0.7264	0.5724	0.2926
Critical isenthalp								
<i>T</i> .....	0.00	[ 13.38	182.77	260.56	293.70	304.10]	307.80	313.82
<i>μ</i> .....	13.580	[ 13.01	5.783	2.463	1.049	0.6050]	0.4470	0.1906
Liquid isenthalps								
<i>T</i> .....	[195.21	198.25	251.57	281.51	297.44]	303.50	305.92	310.43
<i>μ</i> .....	[3.7974	3.6800	2.0194	1.0744	0.5716]	0.3804	0.3041	0.1618
<i>T</i> .....	[245.42	247.07	271.83	287.94	297.79]	302.00	303.81	307.48
<i>μ</i> .....	[1.6720	1.6312	1.0210	0.6239	0.3812]	0.2774	0.2329	0.1423
<i>T</i> .....	[265.03	265.92	280.04	290.11	296.87]	300.00	301.41	304.45
<i>μ</i> .....	[0.9102	0.8924	0.6108	0.4099	0.2751]	0.2127	0.1846	0.1239
<i>T</i> .....	[275.86	275.93	277.16]	278.34	279.39	280.00	280.32	281.14
<i>μ</i> .....	[0.06978	0.06936	0.06202]	0.05514	0.04901	0.04543	0.04357	0.03873
<i>T</i> .....	[259.24	259.26	259.46]	259.67	259.88	260.00	260.07	260.26
<i>μ</i> .....	[0.01096	0.01094	0.01064]	0.01027	0.00993	0.00973	0.00962	0.00931
<i>T</i> .....	[240.54	240.53]	240.40	240.29	240.10	240.00	239.94	239.79
<i>μ</i> .....	[−0.00704	−0.00705]	−0.00723	−0.00742	−0.00761	−0.00773	−0.00781	−0.00801
<i>T</i> .....	[222.19	222.17]	221.66	221.08	220.44	220.00	219.74	218.98
<i>μ</i> .....	[−0.02537	−0.02548]	−0.02778	−0.03040	−0.03329	−0.03528	−0.03464	−0.03989

H<sub>2</sub>O Vapor, unit, °C/kg cm<sup>−2</sup> (5)

°C.....	120	150	200	250	300	350	400
<i>μ</i> .....	5.33	3.63	2.20	1.50	1.15	0.90	0.75

At 165°C and 3.86 kg/cm<sup>2</sup>, *μ* = 3.182 (24).CH<sub>4</sub>, values of *μ* =  $\frac{t_1 - t_2}{p - 1}$  °C/atm. ± ca. 0.05 (21); cf. (15)

<i>p</i> .....	25	17	14.6	27	55
<i>t</i> <sub>1</sub> , °C.....	−77	−78	−78	+10	10
<i>μ</i> .....	0.75	0.75	0.74	0.35	0.40

C<sub>2</sub>H<sub>5</sub>Cl, values of *μ* in °C/atm. for pressures less than 3 atm. (10)

°C.....	0	20	40	60	80	100
<i>μ</i> .....	5.22	4.51	3.86	3.31	2.84	2.43

## Inversion Temperatures

*μ* = 0 at *t*, °C and at *p*<sub>atm</sub>.

<i>t</i>	<i>p</i>	Gas	<i>t</i>	<i>p</i>	Lit.
Air (20)		He.....	−173	(1)	(17)
300.4	90.1	H <sub>2</sub> .....	80.5*	113	(15)
283.0	137.0	Liq. air.....	−133	150	(8, 12)
252.8	176.7		−140	125	(8, 12)
240.1	199.1	CO <sub>2</sub> (liq.).....	−24.0	18 to 100	(2)

\* Temperature at which a drop from *p* to 1 atm. gives zero integrated cooling effect.

## CHANGE IN TEMPERATURE ON ADIABATIC EXPANSION

H<sub>2</sub>O, values of  $10^5 \left( \frac{\partial t}{\partial p} \right)$ , unit, °C/kg cm<sup>−2</sup>

<i>p</i> , kg/cm <sup>2</sup>	Lit.									
	(18)	(1)	(1)	(18)	(18)	(1)	(18)	(1)	(1)	(18)
	0°	20°	25°	37°	40°	54°	60°	80°		
1	−130	−16	+137	+ 66	260	287	390	417	548	492
500	− 20	+68	175	130	273	300	371	417	500	468
1 000	+ 64	132	220	167	279	309	357	413	462	445
1 500	116	183	248	188	279	316	344	406	427	423
2 000	150	215	263	203	279	322	335	397	403	406
3 000	189	251	280	223	284	325	325	381	367	382
4 000		260	283	240		323		366	344	
6 000		194	289			336		349	308	
8 000			355			333		337	279	
10 000						330		330	257	
12 000						320		320	238	

For calculated values 0 – 30°C and 1 to 1000 atm., *v*. (23).

## Miscellaneous Substances

Substance	<i>p</i>	1	500	1000	1500	2000	2500	3000
	°C	$10^5 \frac{(dt)}{(dp)}$ (19)						
Benzene.....	90	2550	2000	1620	1390	1210	1090	990
Urethane.....	80	1300	1072	884	765	702	639	



## Miscellaneous Substances.—(Continued)

Substance	p	1	500	1000	1500	2000	2500	3000
	°C	$10^5 \frac{(dt)}{(dp)} (19)$						
Mix. A*	90	2400	1890	1560	1300	1110	990	880
Phenol	80	1130	999	883	802	726	648	
p-Toluidine	80	1300	1158	1034				
Mix. B*	80	1160	1016	905	782	691	644	
Ethyl alcohol	30	1450	1180	965	805	715	658	
Water	0	-130	-20	+64	+116	+150	+173	+189
	80	492	468	445	423	406	392	382
	25	437	407	380	352	327	308	294
Glycerol	98.2	625	570	520	475	441		
Castor oil	0	785	700	628	564	507	468	448

\* Mix. A is 75 mol % Benzene + 25 mol % Urethane. Mix. B is 75 mol % Phenol + 25 mol % p-Toluidine.

## AQUEOUS SOLUTIONS (22)

Changes of temperature on adiabatic expansion

Wt. % KCl	0.747	7.11	19.43	Wt. % NaCl	5.63	10.68
$\Delta P$	$\Delta t$	$\Delta t$	$\Delta t$	$\Delta P$	$\Delta t$	$\Delta t$
101	-0.07	-0.05	-0.21	101	-0.10	-0.21
200	-0.05	-0.16	-0.39	200	-0.15	-0.34
300	-0.11	-0.26	-0.60	300	-0.24	-0.49
400	-0.12	-0.44	-0.72	400	-0.42	-0.67
498	-0.15	-0.55	-0.96	498	-0.55	-0.79

Wt. % H <sub>2</sub> SO <sub>4</sub>	3.94	7.69	Wt. % ZnSO <sub>4</sub>	2.85	5.55	8.11
$\Delta P$	$\Delta t$	$\Delta t$	$\Delta P$	$\Delta t$	$\Delta t$	$\Delta t$
101	-0.11	-0.12	101	-0.02	-0.05	-0.09
200	-0.12	-0.32	200	-0.04	-0.10	-0.16
300	-0.25	-0.38	300	-0.10	-0.17	-0.24
400	-0.38	-0.58	400	-0.18	-0.24	-0.32
498	-0.54	-0.79	498	-0.27	-0.36	-0.45

Wt. % C <sub>2</sub> H <sub>5</sub> OH	4.99	10.18
Wt. % NaCl	0.60	0.62
$\Delta P$	$\Delta t$	$\Delta t$
101	-0.006	-0.04
200	-0.01	-0.09
300	-0.01	-0.13
400	-0.04	-0.19
498	-0.10	-0.24

Liquid NH<sub>3</sub>, values of  $l = \left(\frac{\partial Q}{\partial p}\right)_T (16)$

Unit, joules per kg/atm.

°C	-44.1	-39.0	-24.2	-0.2	16.5	26.5	35.4	40.3
l	-57	-59	-70	-91	-111	-127	-145	-155

## HEAT OF ISOTHERMAL COMPRESSION

$$Q = \int_0^p f(p) dp$$

H<sub>2</sub>O, values of  $10^5 Q$ , unit g-cal/g (1)

p, kg/cm <sup>2</sup>	0°	20°	40°	60°	80°
0	0.0	0.0	0.0	0.0	0.0
500	0.2	0.7	1.5	2.1	2.6
1 000	0.6	1.6	2.9	4.1	5.0
2 000	1.9	3.8	5.8	7.9	9.2
3 000	4.0	6.4	8.7	11.4	13.1

p, kg/cm <sup>2</sup>	0°	20°	40°	60°	80°
4 000	6.4	8.9	11.6	14.6	16.5
6 000	10.6	14.0	17.3	20.9	23.2
8 000		19.6	23.1	27.0	29.3
10 000			28.7	32.9	35.3
12 000			34.5	38.8	40.8

Calculated values for CS<sub>2</sub>, ether, alcohol and H<sub>2</sub>O (3). Calculated values at 0°C for ethylene chloride, ethyl chloride, ethyl bromide, ethyl iodide, methyl acetate, ethyl acetate, benzene, toluene, xylene, cymene, bromine, mercury, acetone, carbon disulfide, carbon tetrachloride, chloroform and ether (13).

## HEAT OF ELASTIC EXTENSION OF METALS

$$\frac{\Delta t}{\Delta r} = -\frac{aT}{cd}, \text{ where } \Delta r = \text{tension increase and } \Delta t \text{ the corre-}$$

sponding temperature increase,  $a$  = the coefficient of thermal expansion,  $d$  the density,  $c$  the specific heat per gram and  $T$  the temperature in °K;  $Q$  = heat absorbed.

$\Delta r$ , kg/cm <sup>2</sup>	$\Delta t$ , °C	$Q$ , g-cal/cm <sup>2</sup>
Steel at 23.9°C, $d = 7.93$ g/cm <sup>3</sup> (4)		
1656	-0.1369	0.1279
3312	-0.2737	0.2556
4968	-0.4106	0.3836
German silver at 16.4°C, $d = 8.40$ g/cm <sup>3</sup> (7)		
969	-0.1405	0.1135 ± 3%

## TEMPERATURE CHANGE IN PLASTIC EXTENSION (6)

100  $\Delta l/l_0$  = % elongation. $\Delta t_t$  = Temp. rise with tension maintained. $\Delta t_r$  = Temp. rise on relief of residual tension. $\Delta t_w$  = Temp. rise to be expected from work done by tension.

$$\frac{\Delta t_t + \Delta t_r}{\Delta t_w} = R = \text{Ratio of heat evolved to work done.}$$

Metal	100 $\Delta l/l_0$ max.*	$\Delta t_t$	$\Delta t_r$	R
Steel	13.10	9.00	0.37	0.865
Cu	17.45	6.29	0.31	0.92
Al	23.06	5.68	0.28	0.93
Al, single crys.	52.72	8.77	0.19	0.95

\* R is independent of  $\Delta l/l_0$  up to the maximum value studied.

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(For a key to the periodicals see end of volume)

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## HEATS OF SOLUTION OF ORGANIC SUBSTANCES

ERNEST ANDERSON

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 Tables 1 and 2 form a complete index to the whole.\*

TABLE 1.—HEATS OF SOLUTION OF ORGANIC SUBSTANCES IN WATER

$Q$  is expressed as kilojoules evolved per mole solute, at infinite dilution. These systems are arranged according to the  $\mathcal{C}$ -arrangement (*v. Vol. III, p. viii*). Inorganic salts of organic acids will be found immediately following the acid.

Formula	Name	$t, ^\circ\text{C}$	$Q$	Lit. and table numbers
$\text{CHCl}_3$	Chloroform.....	16	9.2	(20)
$\text{CH}_3\text{N}_3$	Cyanamide.....		-15.1	(105)
$\text{CH}_2\text{O}_2$	Formic acid (solid).....	7	-9.83	(10)
	Formic acid (liquid).....	7	0.33	(10); 5
$\text{CH}_3\text{NO}_2$	Nitromethane.....		-2.5	(39)
$\text{CH}_3\text{N}_2\text{O}$	Urea.....		-15.1	(43, 111)
$\text{CH}_3\text{N}_2\text{S}$	Thiourea.....	10	-22.3	(111)
$\text{CH}_3\text{O}$	Methyl alcohol.....		8.37	(14, 68, 69, 70, 75, 81); 6
$\text{CH}_3\text{N}$	Methylamine.....			(47)
$\text{CH}_3\text{N}_2\text{O}_2$	Urea nitrate.....		-45.2	(111)
$\text{CH}_3\text{N}_2\text{O}_2$	Guanidine nitrate.....		-42.7	(111)
$\text{C}_2\text{H}_3\text{Br}_2\text{O}_2$	Tribromoacetic acid.....		4.69	(115); 5
$\text{C}_2\text{HCl}_2\text{O}_2$	Trichloroacetic acid (solid).....		12.1	(106, 115); 5
	Trichloroacetic acid (liquid).....	15	22.08	(115)
	Na trichloroacetate.....		7.28	(106)
$\text{C}_2\text{H}_2\text{Br}_2\text{O}_2$	Dibromoacetic acid.....		11.7	(115); 5
$\text{C}_2\text{H}_2\text{Cl}_2\text{O}_2$	Dichloroacetic acid.....		4.69	(106, 115); 5
$\text{C}_2\text{H}_2\text{O}_2$	Glyoxal.....		-5.23	(66)
	Glyoxal bisulfite.....		-40.4	(66)
$\text{C}_2\text{H}_2\text{O}_4$	Oxalic acid.....		-9.58	(96, 102)
$\text{C}_2\text{H}_2\text{O}_4 \cdot 2\text{H}_2\text{O}$	Oxalic acid.....		-35.5	(96)
$\text{C}_2\text{H}_3\text{BrO}_2$	Bromoacetic acid.....		-12.8	(115); 5
$\text{C}_2\text{H}_3\text{ClO}_2$	Chloroacetic acid (solid).....	16	-14.0	(106, 115)
	Chloroacetic acid (liquid).....	16	1.12	(106, 115)
	Chloral hydrate.....		-3.77	(20, 88, 122)
$\text{C}_2\text{H}_3\text{Cl}_2\text{O}_2$	Oxamic acid.....	12	-29	(111)
	K oxamate.....		-31.0	(110)
$\text{C}_2\text{H}_4\text{O}$	Acetaldehyde.....		15.1	(8)
$\text{C}_2\text{H}_4\text{O}_2$	Acetic acid (solid).....	7	-8.91	(10)
	Acetic acid (liquid).....	14	-9.42	(10)
	Acetic acid (liquid).....	7	1.67	(37); 5
	Acetic acid (liquid).....	23	1.00	(10)
$\text{C}_2\text{H}_4\text{O}_2$	Methyl formate.....	15	4.73	(41)
$\text{C}_2\text{H}_4\text{O}_2$	Glycolic acid.....		-11.55	(66)
	Ba glycolate.....		-21.26	(66)
	Ca glycolate.....		-6.78	(66)
	Ca glycolate ( $3\text{H}_2\text{O}$ ).....		-29.55	(66)
	Ca glycolate ( $5\text{H}_2\text{O}$ ).....		-32.6	(66)
	Cu glycolate.....		-6.78	(66)
	K glycolate.....		-6.86	(66)
	K glycolate ( $0.5\text{H}_2\text{O}$ ).....		-19.7	(66)
	Mg glycolate.....		-18.41	(66)
	Na glycolate.....		-10.30	(66)
	Na glycolate ( $0.5\text{H}_2\text{O}$ ).....		-14.6	(66)
	$\text{NH}_4$ glycolate.....		-13.52	(66)
	Pb glycolate.....		-24.02	(66)
	Sr glycolate.....		-5.02	(66)
	Zn glycolate.....		-2.76	(66)
$\text{C}_2\text{H}_4\text{O}_4$	Glyoxylic acid.....	11	-10.5	(67)
	Ca glyoxylate.....		-9.37	(67)
	Na glyoxylate.....		-20.1	(67)
$\text{C}_2\text{H}_5\text{NO}$	Acetamide.....	23	-8.33	(122)
$\text{C}_2\text{H}_5\text{NO}_2$	Glycocoll.....		-14.98	(106)
$\text{C}_2\text{H}_5\text{NO}_2$	Ethyl nitrate.....		4.14	(15)
$\text{C}_2\text{H}_5\text{O}$	Ethyl alcohol.....	13	10.63	(14, 48, 75, 81, 138); 3, 6
$\text{C}_2\text{H}_5\text{O}$	Dimethyl ether.....	17	34.7	(21)

\* The numbers in the last column not in parentheses are numbers of other tables in this section which should be consulted for further data.

TABLE 1.—(Continued)

Formula	Name	$t, ^\circ\text{C}$	$Q$	Lit. and table numbers
$\text{C}_2\text{H}_5\text{O}_2$	Glycol.....		7.1	(23, 73); 3
$\text{C}_2\text{H}_5\text{N}_2\text{O}_2$	Urea formate.....		-30.1	(111)
$\text{C}_2\text{H}_5\text{O}_4\text{S}$	Ethyl sulfuric acid.....			
	Ba ethylsulfate.....		2.9	(14)
	Ba ethylsulfate ( $2\text{H}_2\text{O}$ ).....		-18.0	(14)
	Na ethylsulfate.....		-4.2	(14)
	Na ethylsulfate ( $\text{H}_2\text{O}$ ).....		-13.0	(14)
$\text{C}_2\text{H}_7\text{N}$	Ethylamine.....	19	26.49	(6, 22, 58)
$\text{C}_2\text{H}_5\text{ClN}$	Ethylamine hydrochloride.....		-9.33	(67)
$\text{C}_2\text{H}_5\text{N}_2$	Ethylenediamine.....		31.8	(60)
$\text{C}_2\text{H}_{10}\text{Cl}_2\text{N}_2$	Ethylenediamine dihydrochloride.....		-31.60	(60)
$\text{C}_2\text{H}_{12}\text{N}_4\text{O}_4\text{S}$	Guanidine sulfate.....		-28.25	(111)
$\text{C}_2\text{H}_2\text{Br}_2\text{O}_4$	Dibromomalononic acid.....		8.45	(108)
	KH dibromomalonate.....		-23.4	(108)
	K <sub>2</sub> dibromomalonate.....		-41.60	(108)
$\text{C}_2\text{H}_3\text{N}_2\text{O}_2$	Cyanuric acid.....		v. p. 182	
$\text{C}_2\text{H}_4\text{Br}_2\text{O}_2$	$\alpha$ -Dibromopropionic acid.....	13	6.86	(125)
	K $\alpha$ -dibromopropionate.....		2.18	(125)
	K $\alpha$ -dibromopropionate ( $\text{H}_2\text{O}$ ).....		-12.1	(125)
$\text{C}_2\text{H}_4\text{N}_2\text{O}_2$	Hydantoin.....		-25.1	(111)
$\text{C}_2\text{H}_4\text{O}_4$	Malonic acid.....		-18.8	(108)
	Ag <sub>2</sub> malonate.....		-41.0	(108)
	KH malonate.....		-21.3	(108)
	K <sub>2</sub> malonate.....		8.8	(108)
	K <sub>2</sub> malonate ( $2\text{H}_2\text{O}$ ).....		-23.4	(108)
	LiH malonate.....		-5.9	(108)
	Li <sub>2</sub> malonate.....		14.6	(108)
	NaH malonate.....		-25.5	(108)
	Na <sub>2</sub> malonate.....		13.0	(108)
	Na <sub>2</sub> malonate ( $\text{H}_2\text{O}$ ).....		6.3	(108)
	$\text{NH}_4\text{H}$ malonate.....		-25.1	(108)
	( $\text{NH}_4$ ) <sub>2</sub> malonate.....		-10.5	(108)
$\text{C}_2\text{H}_4\text{O}_5$	Tartronic acid.....		-15.69	(108)
	KH tartronate.....	14	-31.4	(108)
	K <sub>2</sub> tartronate.....		-19.88	(108)
	Na <sub>2</sub> tartronate.....	10	-12.6	(108)
$\text{C}_2\text{H}_5\text{N}$	Propionitrile.....		-3.26	(120)
$\text{C}_2\text{H}_5\text{N}_2\text{O}_2$	Acetylurea.....		-28.5	(110)
$\text{C}_2\text{H}_5\text{N}_2\text{O}_2$	Hydantoic acid.....		-27.2	(111)
$\text{C}_2\text{H}_5\text{O}$	Allyl alcohol.....		8.37	(14)
$\text{C}_2\text{H}_5\text{O}$	Propionaldehyde.....		17	(14)
$\text{C}_2\text{H}_5\text{O}$	Acetone.....		10.5	(14); 4
$\text{C}_2\text{H}_5\text{O}_2$	Propionic acid.....		2.59	(108); 5
	Ba propionate.....		28.75	(11)
	K propionate.....		12.64	(108)
	Na propionate.....		12.76	(108)
$\text{C}_2\text{H}_5\text{O}_2$	Ethyl formate.....	10	8.8	(41)
$\text{C}_2\text{H}_7\text{N}$	Allylamine.....		19.59	(58, 87)
$\text{C}_2\text{H}_7\text{NO}$	Propionamide.....	15	-4	(35)
$\text{C}_2\text{H}_7\text{NO}_2$	Urethane.....	23	-15.9	(122)
$\text{C}_2\text{H}_5\text{N}_2\text{O}$	Ethylurea.....	14	-9.6	(111)
$\text{C}_2\text{H}_5\text{N}_2\text{O}_2$	Urea acetate.....		-36.8	(111)
$\text{C}_2\text{H}_5\text{O}$	<i>n</i> -Propyl alcohol.....		12.76	(48, 70); 6
$\text{C}_2\text{H}_5\text{O}$	Isopropyl alcohol.....		15.74	(75, 76)
$\text{C}_2\text{H}_5\text{O}_2$	Methylal.....		13.4	(40)
$\text{C}_2\text{H}_5\text{O}_2$	Glycerol.....		6.3	(8, 14, 71, 72, 89, 100); 4
$\text{C}_2\text{H}_5\text{N}$	Propylamine.....		25.74	(68)
$\text{C}_2\text{H}_5\text{N}$	Trimethylamine.....		36.62	(22, 58)
$\text{C}_2\text{H}_{10}\text{ClN}$	Trimethylamine hydrochloride.....	18	-2.1	(22)
$\text{C}_2\text{H}_5\text{N}_2\text{O}_4$	Alloxan.....		-17.6	(112)
$\text{C}_2\text{H}_4\text{O}_4$	Fumaric acid.....		-24.7	(82, 86)
$\text{C}_2\text{H}_4\text{O}_4$	Maleic acid.....		-18.58	(82, 86)
$\text{C}_2\text{H}_5\text{NO}_2$	Succinimide.....	22	-18.0	(122)
$\text{C}_2\text{H}_5\text{N}_2\text{O}_2$	Allantoin.....		-31.4	(110)
$\text{C}_2\text{H}_5\text{O}_2$	Succinic acid.....	11	-26.8	(54)
	KH succinate.....		-22.39	(105)
	KH succinate ( $\text{H}_2\text{O}$ ).....		-31.8	(54)



TABLE 1—(Continued)

Formula	Name	<i>t</i> , °C	<i>Q</i>	Lit. and table numbers
$C_4H_5O_4$	K <sub>2</sub> succinate.....		0.8	(54)
	K <sub>2</sub> succinate (H <sub>2</sub> O).....		-14.2	(54)
	NaH succinate.....		-11.7	(108)
	Na <sub>2</sub> succinate.....		10.0	(108)
	Na <sub>2</sub> succinate (6H <sub>2</sub> O).....		-46.0	(54)
	NH <sub>4</sub> H succinate.....		-20.5	(54)
$C_4H_5O_4$	(NH <sub>4</sub> ) <sub>2</sub> succinate.....		-14.6	(108)
	Isosuccinic acid.....	6	-14.31	(108)
	KH isosuccinate.....		-15.74	(108)
	KH isosuccinate (H <sub>2</sub> O).....		-19.08	(108)
	K <sub>2</sub> isosuccinate.....		13.06	(108)
	K <sub>2</sub> isosuccinate (H <sub>2</sub> O).....		8.16	(108)
$C_4H_5O_4$	K <sub>2</sub> isosuccinate (2H <sub>2</sub> O).....		5.90	(108)
	Na <sub>2</sub> isosuccinate.....		20.5	(108)
	Dimethyl oxalate.....		-9.37	(18)
	Malic acid.....	15	-13.8	(107, 108)
		20	-13.18	(85)
	KH malate.....		-24.3	(107, 108)
$C_4H_5O_4$	KH malate (H <sub>2</sub> O).....		-27.6	(108)
	K <sub>2</sub> malate.....		-6.49	(107, 108)
	NaH malate.....	21	-6.95	(107, 108)
	NaH malate (H <sub>2</sub> O).....	18	-11.17	(108)
	Na <sub>2</sub> malate.....	21	7.45	(107, 108)
	<i>d</i> -Tartaric acid.....		-14.44	(36)
$C_4H_5O_4$	KH tartrate.....	12	-48.5	(95)
	K <sub>2</sub> tartrate.....		-14.90	(10)
	K <sub>2</sub> tartrate (0.5H <sub>2</sub> O).....		-23.27	(10)
	KSbO tartrate.....	12	-21.3	(91)
	KSbO tartrate (0.5H <sub>2</sub> O).....		-22.2	(91)
	NaH tartrate.....		-23.69	(10)
$C_4H_5O_4$	NaH tartrate (H <sub>2</sub> O).....		-35.74	(10)
	NaK tartrate.....		-7.83	(10)
	NaK tartrate (4H <sub>2</sub> O).....		-51.64	(10)
	Na <sub>2</sub> tartrate.....		-4.69	(10)
	Na <sub>2</sub> tartrate (2H <sub>2</sub> O).....		-24.61	(10)
	<i>dl</i> -Tartaric acid.....		-22.68	(36, 108)
$C_4H_5O_4$	<i>dl</i> -Tartaric acid (H <sub>2</sub> O).....		-28.88	(36)
	<i>meso</i> -Tartaric acid.....		-21.93	(36, 108)
	Chloral alcoholate.....		0.0	(24)
	Aspartic acid.....	16	-30.34	(32)
	<i>n</i> -Butyric acid.....			5
	Na <i>n</i> -butyrate.....		17.74	(11)
$C_4H_5O_4$	Na <i>n</i> -butyrate (3H <sub>2</sub> O).....		14.40	(11)
	Isobutyric acid.....		4.2	(84)
	Ca isobutyrate (5H <sub>2</sub> O).....		13.0	(83)
	Ethyl acetate.....	15	12.81	(18)
	Urea oxalate.....	17	-74.5	(111)
	Isobutyl alcohol.....		12.1	(14, 70)
$C_4H_5O_4$	Trimethyl carbinol.....	15	13.52	(77)
	Ethyl ether.....	13	-24.7	(17)
	Erythritol.....		-22.2	(38, 74)
	Diethylamine.....		34.40	(58)
	Isobutylamine.....		25	(58)
	Diethylamine hydrochloride.....		-6.24	(7)
$C_4H_5O_4$	Thiouric acid (1.5H <sub>2</sub> O).....		-44.8	(112)
	K <sub>2</sub> thiourate.....		-69.5	(112)
	Na <sub>2</sub> thiourate.....		-26.8	(112)
	Uric acid.....			
	K urate.....		-35.2	(112)
	Pyridine.....	22	8.87	(30, 58)
$C_4H_5O_4$	Dimethylparabanic acid.....		-19.46	(110)
	Pseudouric acid.....			
	K pseudourate (H <sub>2</sub> O).....		-28.9	(112)
	Citraconic acid.....		-11.7	(83)
	Itaconic acid.....		-24.78	(83)
	Mesaconic acid.....	19	-23.0	(83)
$C_4H_5O_4$	Acetylacetone.....		-2.68	(61, 120)
	Levulinic acid (solid).....		-15.02	(124)
	Levulinic acid (liquid).....		-5.82	(124)
	K levulinate.....		6.03	(124)
	Na levulinate.....		5.65	(124)
	Glutaric acid.....		-22.6	(108)
$C_4H_5O_4$	KH glutarate.....		-18.58	(108)
	K <sub>2</sub> glutarate.....		19.13	(108)
	Pyrotartaric acid.....		-21	(108)
	KH pyrotartrate.....		-13.0	(108)
	KH pyrotartrate (H <sub>2</sub> O).....		-17.6	(108)
	K <sub>2</sub> pyrotartrate.....		19.3	(108)

TABLE 1.—(Continued)

Formula	Name	<i>t</i> , °C	<i>Q</i>	Lit. and table numbers
$C_6H_5O_4$	Monoethyl malonate.....		2.5	(108)
	K ethyl malonate.....		-2.72	(108)
$C_6H_5O_4$	Isovaleric acid.....		2.9	(12)
$C_6H_5O_4$	Trimethylacetic acid.....			
	K trimethylacetate.....	16	30.76	(10)
$C_6H_5O_4$	Piperidine.....	21	27.04	(30, 58)
$C_6H_5O_4$	Piperidine hydrochloride.....		-4	(59)
$C_6H_5O_4$	Isoamyl alcohol.....		11.7	(14, 70)
$C_6H_5O_4$	Amylamine.....		21.13	(58, 87)
$C_6H_5O_4$	Amylamine hydrochloride.....		-5.73	(87)
$C_6H_5O_4$	1, 3-Dihydroxy-2, 4, 6-tri-bromobenzene.....		-9.2	(45)
$C_6H_5O_4$	Picric acid.....		-29.7	(9)
	Ba picrate.....		-19.7	(120)
	Ba picrate (H <sub>2</sub> O).....		-39.3	(120)
	Ba picrate (6H <sub>2</sub> O).....		-61.73	(120)
	Ca picrate.....		9.2	(120)
	Ca picrate (6H <sub>2</sub> O).....		-62.4	(120)
	Cu picrate.....		13.8	(120)
	Cu picrate (8H <sub>2</sub> O).....		-73.7	(120)
	K picrate.....		-42	(9, 120)
	Mg picrate.....		61.5	(120)
	Mg picrate (8H <sub>2</sub> O).....		-66.5	(120)
	Na picrate.....		-26.95	(9, 120)
	NH <sub>4</sub> picrate.....		-36.4	(9, 120)
	Pb picrate.....		-29.7	(120)
	Pb picrate (2H <sub>2</sub> O).....		-55.2	(120)
	Sr picrate.....		3.3	(120)
	Sr picrate (6H <sub>2</sub> O).....		-60.3	(120)
	Zn picrate.....		48.1	(120)
	Zn picrate (8H <sub>2</sub> O).....		-66.5	(120)
$C_6H_5O_4$	Quinone.....		-16.7	(44)
$C_6H_5O_4$	<i>p</i> -Bromophenol.....		-15.5	(125)
$C_6H_5O_4$	Phenyldiazonium chloride.....		-7.70	(123)
$C_6H_5O_4$	<i>o</i> -Nitrophenol.....		-26.4	(1)
	Na <i>o</i> -nitrophenate.....		-7.5	(1)
$C_6H_5O_4$	<i>m</i> -Nitrophenol.....		-21.8	(1)
	Na <i>m</i> -nitrophenate.....		13.0	(108)
$C_6H_5O_4$	<i>p</i> -Nitrophenol.....		-18.8	(1)
	Na <i>p</i> -nitrophenate.....		11.3	(1)
$C_6H_5O_4$	Catechol.....		-14.6	(44, 78)
$C_6H_5O_4$	Resorcinol.....	10	-16.57	(44, 78, 88, 123)
$C_6H_5O_4$	Hydroquinol.....		-18.4	(44, 78)
$C_6H_5O_4$	Phloroglucinol.....		-6.91	(44)
$C_6H_5O_4$	Phloroglucinol (H <sub>2</sub> O).....		-28.0	(44)
$C_6H_5O_4$	Pyrogallol.....		-15.5	(44, 78, 88)
$C_6H_5O_4$	<i>o</i> -Chloroaniline.....		-2.34	(106)
$C_6H_5O_4$	<i>m</i> -Chloroaniline.....		-3.47	(106)
$C_6H_5O_4$	<i>p</i> -Chloroaniline.....		-21.39	(106)
$C_6H_5O_4$	<i>p</i> -Nitroaniline.....		-15.65	(106)
$C_6H_5O_4$	Phenol (solid).....		-10.9	(5, 78, 88, 100)
$C_6H_5O_4$	Benzenesulfonic acid.....			
	Ba benzenesulfonate.....		10.9	(13)
	Ba benzenesulfonate (3H <sub>2</sub> O).....		-10.9	(13)
	Na benzenesulfonate.....	14	-3.3	(13)
	Na benzenesulfonate (2H <sub>2</sub> O).....		-14.2	(13)
$C_6H_5O_4$	<i>o</i> -Phenolsulfonic acid.....			
	Ba <i>o</i> -phenolsulfonate (H <sub>2</sub> O).....		-56.5	(3)
	K <i>o</i> -phenolsulfonate (2H <sub>2</sub> O).....		-40.6	(3)
$C_6H_5O_4$	Aconitic acid.....		-17.6	(7)
$C_6H_5O_4$	Phenol-2, 4-disulfonate.....			
	Ba phenol-2, 4-disulfonate (4H <sub>2</sub> O).....		-33.1	(3)
$C_6H_5O_4$	<i>o</i> -Chloroaniline hydrochloride.....		-18.33	(106)
$C_6H_5O_4$	<i>m</i> -Chloroaniline hydrochloride.....		-16.45	(106)
$C_6H_5O_4$	<i>p</i> -Chloroaniline hydrochloride.....		-14.61	(106)
$C_6H_5O_4$	Aniline.....	16	-0.75	(29)
		24	-2.30	(29)
$C_6H_5O_4$	Aniline hydrochloride.....		-11.43	(29)
$C_6H_5O_4$	Phenylhydrazine (liquid).....	21	1.21	(83)
	Phenylhydrazine (H <sub>2</sub> O).....		-31.0	(83)
$C_6H_5O_4$	<i>m</i> -Phenylenediamine.....		-13.4	(122)
$C_6H_5O_4$	<i>p</i> -Phenylenediamine.....		-15.9	(122)
$C_6H_5O_4$	Aniline nitrate.....		-28.17	(29)



TABLE 1.—(Continued)

Formula	Name	<i>t</i> , °C	<i>Q</i>	Lit. and table numbers
$C_6H_5O_3$	Tricarballic acid.....		-27.2	(108)
	$KH_2$ tricarballic acid.....		-28.0	(108)
	$K_2H$ tricarballic acid.....		-16.7	(108)
	$K_3$ tricarballic acid.....		13.0	(108)
	$Na_3$ tricarballic acid.....		27.6	(108)
$C_6H_5O_7$	Citric acid.....		-22.6	(88, 108)
	$KH_2$ citrate.....		-33.5	(108)
	$K_2H$ citrate.....		-28.0	(108)
	$K_3$ citrate.....		11.8	(108)
	$NaH_2$ citrate.....		-26.57	(108)
	$Na_2H$ citrate.....		-5.11	(108)
	$Na_3$ citrate.....		22.05	(108)
$C_6H_5ClN_2$	Phenylhydrazine hydrochloride.....		-24.94	(114)
$C_6H_{10}O_3$	Ethyl acetoacetate.....		5.27	(80)
	$Na$ ethyl acetoacetate.....		18.4	(79)
$C_6H_{10}O_4$	Diethyl oxalate.....	15	12.89	(18)
$C_6H_{11}Cl_2N_2$	<i>o</i> -Phenylenediamine trihydrochloride ( $5H_2O$ ).....		-34.3	(122)
$C_6H_{12}N_4$	Hexamethylenetetramine.....		20.1	(82)
$C_6H_{12}O$	Cyclohexanol (solid).....		8.12	(82)
	Cyclohexanol (liquid).....		9.8	(82)
$C_6H_{12}O_6$	Inositol.....	18	-14.15	(21)
$C_6H_{12}ClN_4$	Hexamethylenetetramine hydrochloride.....	15	-16.49	(82)
$C_6H_{12}N_4O_3$	Hexamethylenetetramine nitrate.....		-23.02	(82)
$C_6H_{12}N_4O_4S$	Hexamethylenetetramine sulfate.....		-6.70	(82)
$C_6H_{12}N_6O_4$	Hexamethylenetetramine dinitrate.....		-59.8	(82)
$C_6H_{14}O_4$	Dulcitol.....		-24.7	(14)
$C_6H_{14}O_6$	Mannitol.....	23	-22.01	(14, 122)
$C_6H_{15}IS$	Triethylsulfonium iodide.....		-24.06	(7)
$C_6H_{15}N$	Dipropylamine.....		31.60	(88)
$C_6H_{15}N$	Triethylamine.....		42	(88, 87)
$C_6H_{15}ClN$	Triethylamine hydrochloride.....		-2.22	(87)
$C_7H_5O_7$	Meconic acid.....		-38.1	(27)
$C_7H_5ClO_3$	<i>o</i> -Chlorobenzoic acid.....		-26.9	(116)
	$K$ <i>o</i> -chlorobenzoate ( $0.5H_2O$ ).....		1.51	(116)
$C_7H_5NO_3$	<i>o</i> -Nitrobenzoic acid.....		-22.2	(1, 80)
	$Na$ <i>o</i> -nitrobenzoate.....		16.3	(1)
$C_7H_5NO_3$	<i>m</i> -Nitrobenzoic acid.....		-23.4	(1, 106)
	$Na$ <i>m</i> -nitrobenzoate.....		-4.6	(1, 106)
$C_7H_5NO_3$	<i>p</i> -Nitrobenzoic acid.....		-37.2	(1)
	$Na$ <i>p</i> -nitrobenzoate.....		-4.19	(1)
$C_7H_5O_2$	Salicylaldehyde.....		0.4	(25)
$C_7H_5O_2$	<i>p</i> -Hydroxybenzaldehyde.....		-20.5	(25)
$C_7H_5O_2$	Benzoic acid.....		-27.2	(9, 106)
	$Ca$ benzoate.....		19.7	(9)
	$K$ benzoate.....		-6.3	(9)
	$Na$ benzoate.....		3.3	(9)
	$NH_4$ benzoate.....		-11.3	(9)
$C_7H_5O_7$	<i>o</i> -Hydroxybenzoic acid.....		-26.57	(46)
	$Na$ <i>o</i> -hydroxybenzoate.....		-9.17	(108)
$C_7H_5O_7$	<i>m</i> -Hydroxybenzoic acid.....		-25.86	(46)
$C_7H_5O_7$	<i>p</i> -Hydroxybenzoic acid.....		-24.19	(46)
	<i>p</i> -Hydroxybenzoic acid ( $H_2O$ ).....		-32.31	(46)
$C_7H_5O_4$	3, 4-Dihydroxybenzoic acid ( $H_2O$ ).....	17	-29.7	(25)
$C_7H_5O_5$	Gallie acid ( $H_2O$ ).....		-29.7	(25)
$C_7H_7NO_2$	<i>o</i> -Hydroxybenzamide.....		-18.16	(1)
	$Na$ <i>o</i> -hydroxybenzamide.....		1.46	(1)
$C_7H_7NO_2$	<i>m</i> -Hydroxybenzamide.....		-17.41	(106)
	$Na$ <i>m</i> -hydroxybenzamide.....		5.9	(106)
$C_7H_7NO_2$	<i>p</i> -Hydroxybenzamide.....		-22.56	(1)
	$Na$ <i>p</i> -hydroxybenzamide.....		8.0	(1)
$C_7H_7ClNO_2$	<i>m</i> -Hydroxybenzamide hydrochloride.....		-29.3	(106)
$C_7H_7O$	<i>o</i> -Cresol.....		-8.8	(28)
$C_7H_7O$	<i>p</i> -Cresol.....		-8.8	(28)
$C_7H_7O_2$	Ordnol.....		-10.9	(44)
	Ordnol ( $H_2O$ ).....		-22.6	(44)
$C_7H_7O_2$	<i>o</i> -Hydroxybenzyl alcohol.....		-13.4	(28)
$C_7H_7O_2S$	<i>p</i> -Toluenesulfonic acid.....		-20.9	(28)
$C_7H_7N$	$K$ <i>p</i> -toluenesulfonate.....		10.71	(58, 87)

TABLE 1.—(Continued)

Formula	Name	<i>t</i> , °C	<i>Q</i>	Lit. and table numbers
$C_7H_7N$	<i>p</i> -Toluidine.....		-18.8	(7)
$C_7H_7NO_2$	Pyridine acetate.....		8.069	(109)
$C_7H_{15}ClN$	Benzylamine hydrochloride.....		-16.03	(87)
$C_7H_{15}ClN$	<i>p</i> -Toluidine hydrochloride.....		-13.60	(7)
$C_7H_{15}O_3$	Quinic acid.....	17	-12.76	(27)
$C_8H_5N_4O_3$	Alloxantin ( $2H_2O$ ).....		-44.4	(112)
$C_8H_5O_4$	Phthalic acid.....		-20.38	(87)
	$Na_2$ phthalate.....		1.00	(87)
	$Na_2$ isophthalate.....		-3.3	(87)
	$Na_2$ terephthalate.....		-2.5	(87)
$C_8H_5O_4$	Piperonylic acid.....		-38.1	(26)
$C_8H_5O_5$	Anisic acid.....		-33.1	(26)
$C_8H_5O_5$	Mandelic acid.....	18	-12.93	(26)
$C_8H_5O_5$	Vanillin.....		-21.8	(26)
$C_8H_5O_5$	Vanillic acid.....	14	-21.59	(26)
$C_8H_{11}N_4O_3$	Caffeine.....		-11.47	(112)
	Caffeine ( $H_2O$ ).....		-18.67	(112)
$C_8H_{11}NO_4$	Diethyl cyanomalonate.....		10.0	(92)
	$Ba$ ethyl cyanomalonate.....		-20.5	(92)
	$Ba$ ethyl cyanomalonate ( $4H_2O$ ).....		-10.9	(92)
$C_8H_{11}O_4$	Caprylic acid.....		0.67	(106)
$C_8H_{11}N$	Diisobutylamine.....		29.50	(88)
$C_8H_{11}O_4$	Veratric acid.....		-25.5	(26)
$C_{10}H_{11}NO_4$	Nitrocumic acid.....		-5.0	(1)
	$Na$ nitrocumate.....		15.9	(1)
$C_{10}H_{11}O_2$	Cumic acid.....		-7.5	(42)
$C_{10}H_{11}NO_3$	Nitrocamphor.....		-11.7	(42)
	Hydrated nitrocamphor.....		27.45	(88)
$C_{10}H_{11}Cl_2N_2$	Nicotine dihydrochloride.....		-13.4	(34)
$C_{10}H_{11}O_2$	Campholenic acid.....		-2.1	(27)
$C_{10}H_{11}O_4$	Camphoric acid.....		0	(88)
$C_{10}H_{11}O$	Menthol.....		15.36	(27)
$C_{12}H_5O_{12}$	Mellitic acid.....		-43.9	(26)
$C_{12}H_{11}ClN_2$	Benzidine hydrochloride.....		-31.4	(114)
$C_{12}H_{11}Cl_2N_2$	Benzidine dihydrochloride.....		-24.7	(114)
$C_{12}H_{11}N_2O_4S$	Aniline sulfate.....		-19.38	(29)
$C_{12}H_{11}O_{10}$	Dextrin.....		-1.12	(126)
$C_{12}H_{11}O_{11}$	Lactose.....		10.5	(96)
	Lactose ( $H_2O$ ).....	23	-15.5	(96)
$C_{12}H_{11}O_{11}$	Sucrose.....	18	-5.52	(14, 106, 122)
$C_{12}H_{11}O_7$	Salicin.....		-12.26	(26)
$C_{14}H_{15}N_2O_4$	<i>m, m'</i> -Asobenzoic acid.....		18.4	(1)
	$Na_2$ <i>m, m'</i> -asobenzoate.....		-7.5	(1)
	$Na_2$ <i>p, p'</i> -asobenzoate.....		-7.5	(1)
	Tannic acid.....		0.25	(124)
$C_{15}H_{15}O_3$	Tetramethyldiaminodiphenylmethane.....	18	35.2	(28)
$C_{17}H_{21}N_2$	Raffinose.....		-40.6	(28)
$C_{17}H_{21}O_{10}$	Raffinose ( $5H_2O$ ).....		28.9	(1)
$C_{20}H_{21}N_2O_4$	Asocumic acid.....		43.1	(1)
$C_{20}H_{21}N_2O_4$	$Na_2$ asocumate.....		-0.4	(126)
$C_{20}H_{21}N_2O_4$	Hydrasocumic acid.....			
$C_{20}H_{21}N_2O_4$	$Na_2$ hydrasocumate.....			
$C_{20}H_{21}O_{11}$	Inulin.....			

TABLE 2.—HEATS OF SOLUTION OF BINARY ORGANIC SYSTEMS

C-Table.—C-Arrangement (v. Vol. III, p. viii)

The B-component where italicized is the solute, and otherwise is the solvent. *Q* is expressed in kilojoules evolved per mole solute, dissolved in more than one mole solvent; at room temperature where not given.

B-Component		Q	Lit. and Table No.*
Formula	Name (and temp., °C)		
CCl <sub>4</sub>			
CS <sub>2</sub>	Carbon bisulfide.....	- 1.76	(127); 3
CHCl <sub>3</sub>	Chloroform.....		3
CH <sub>3</sub> O	Methyl alcohol.....	0.67	(127)

\* The numbers not in parentheses are numbers of other tables in this section which should be consulted for further data.



TABLE 2.—(Continued)

B-Component		Q	Lit. and Table No.*
Formula	Name (and temp., °C)		
CCl <sub>4</sub> .—(Continued)			
CH <sub>4</sub> O	Methyl alcohol.....	— 6.7	(127)
C <sub>2</sub> H <sub>4</sub> Br <sub>2</sub>	Ethylene bromide.....		3
C <sub>2</sub> H <sub>4</sub> O <sub>2</sub>	Acetic acid.....	— 0.8	(127)
C <sub>2</sub> H <sub>4</sub> O <sub>2</sub>	Acetic acid.....	— 1.88	(127)
C <sub>2</sub> H <sub>6</sub> O	Ethyl alcohol.....	0.88	(127)
C <sub>3</sub> H <sub>6</sub> O	Acetone.....	— 1.7	(127)
C <sub>3</sub> H <sub>8</sub> O	Propyl alcohol.....	0.8	(127)
C <sub>4</sub> H <sub>8</sub> O <sub>2</sub>	Ethyl acetate.....	— 0.29	(127, 130); 3
C <sub>4</sub> H <sub>10</sub> O	Isobutyl alcohol.....	— 1.3	(127)
C <sub>4</sub> H <sub>10</sub> O	Ethyl ether.....	2.1	(127)
C <sub>5</sub> H <sub>5</sub> N	Pyridine.....	1.3	(127)
C <sub>5</sub> H <sub>5</sub> N	Pyridine.....	— 1.3	(127)
C <sub>6</sub> H <sub>6</sub>	Benzene.....	— 0.67	(127); 3
C <sub>6</sub> H <sub>6</sub>	Benzene.....	— 0.50	(127); 3, 4
C <sub>6</sub> H <sub>7</sub> N	Aniline.....	— 4.52	(127); 3
C <sub>6</sub> H <sub>7</sub> N	Aniline.....	— 8.8	(127)
C <sub>7</sub> H <sub>6</sub> O <sub>2</sub>	Benzoic acid.....	—14.6	(127)
C <sub>7</sub> H <sub>6</sub> O <sub>2</sub>	Salicylic acid.....	—11.3	(127)
C <sub>7</sub> H <sub>8</sub>	Toluene.....		3, 4
C <sub>7</sub> H <sub>8</sub> NO <sub>2</sub>	Pyridine acetate.....	— 0.448	(109)
C <sub>7</sub> H <sub>16</sub>	Heptane.....	— 0.71	(127)
C <sub>7</sub> H <sub>16</sub>	Heptane.....	— 1.00	(127)
C <sub>12</sub> H <sub>24</sub> O <sub>2</sub>	Lauric acid.....	—35.6	(127)
C <sub>22</sub> H <sub>44</sub> O <sub>2</sub>	Erucic acid.....	—50.6	(127)

CS<sub>2</sub>

CHCl <sub>3</sub>	Chloroform.....	- 2.43	(127); 3, 4
C <sub>2</sub> H <sub>4</sub> Br <sub>2</sub>	Ethylene bromide.....		3
C <sub>2</sub> H <sub>6</sub> O	Ethyl alcohol.....	- 6.7	(127); 4
C <sub>3</sub> H <sub>6</sub> O	Acetone.....	- 7.5	(127); 4
C <sub>4</sub> H <sub>8</sub> O <sub>2</sub>	Ethyl acetate.....	- 6.53	(127); 3
C <sub>4</sub> H <sub>10</sub> O	Ethyl ether.....	- 4.2	(127); 3
C <sub>6</sub> H <sub>6</sub>	Benzene.....	- 2.80	(127); 3, 4
C <sub>6</sub> H <sub>12</sub> O <sub>2</sub>	Paraldehyde.....		3
C <sub>7</sub> H <sub>8</sub>	Toluene.....		4
C <sub>7</sub> H <sub>16</sub>	Heptane.....	- 2.85	(127)
C <sub>10</sub> H <sub>7</sub> NO <sub>2</sub>	Nitronaphthalene.....	-22.68	(88)
C <sub>10</sub> H <sub>8</sub>	Naphthalene.....	-20.9	(88)
C <sub>10</sub> H <sub>16</sub>	Pinene.....		3
C <sub>12</sub> H <sub>10</sub> N <sub>2</sub>	Azobenzene.....	-20.84	(88)
C <sub>12</sub> H <sub>11</sub> N	Diphenylamine.....	-15.0	(88)

CHBr<sub>3</sub>, Bromoform

C <sub>7</sub> H <sub>8</sub>	Toluene.....		3
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CHCl<sub>3</sub>, Chloroform

CH <sub>4</sub> O	Methyl alcohol.....	4.77	(127); 3
C <sub>2</sub> H <sub>5</sub> Cl <sub>2</sub> O <sub>2</sub>	Chloral hydrate (22°).....	-25.07	(122)
C <sub>2</sub> H <sub>4</sub> Br <sub>2</sub>	Ethylene bromide.....		3
C <sub>2</sub> H <sub>4</sub> O	Acetaldehyde.....		3
C <sub>2</sub> H <sub>4</sub> O <sub>2</sub>	Acetic acid.....	2.43	(127)
C <sub>2</sub> H <sub>6</sub> O <sub>2</sub>	Acetic acid.....	2.1	(127)
C <sub>2</sub> H <sub>6</sub> O	Ethyl alcohol.....	6.03	(127); 3
C <sub>3</sub> H <sub>6</sub> O	Acetone.....	4.85	(127); 3, 4
C <sub>3</sub> H <sub>6</sub> O	Acetone.....	8.0	(127, 128)
C <sub>3</sub> H <sub>7</sub> NO <sub>2</sub>	Urethane (24°).....	-19.3	(122)

\* The numbers not in parentheses are numbers of other tables in this section which should be consulted for further data.

TABLE 2.—(Continued)

B-Component		Q	Lit. and Table No.*
Formula	Name (and temp., °C)		
CHCl <sub>3</sub> .—(Continued)			
C <sub>3</sub> H <sub>8</sub> O	<i>n</i> -Propyl alcohol.....	4.69	(127); 3
C <sub>4</sub> H <sub>8</sub> O <sub>2</sub>	Ethyl acetate.....	5.61	(127); 3
C <sub>4</sub> H <sub>8</sub> O <sub>2</sub>	<i>Ethyl acetate</i> .....	9.08	(127)
C <sub>4</sub> H <sub>10</sub> O	Ethyl ether.....	8.41	(127); 3
C <sub>4</sub> H <sub>10</sub> O	<i>Ethyl ether</i> .....	8.8	(127); 4
C <sub>4</sub> H <sub>10</sub> O	Isobutyl alcohol.....		3
C <sub>5</sub> H <sub>5</sub> N	Pyridine.....	6.19	(127)
C <sub>5</sub> H <sub>5</sub> N	<i>Pyridine</i> .....	7.70	(127)
C <sub>5</sub> H <sub>12</sub> O	Isoamyl alcohol.....		3
C <sub>6</sub> H <sub>5</sub> Cl	Chlorobenzene.....		3
C <sub>6</sub> H <sub>5</sub> NO <sub>2</sub>	<i>o</i> -Nitrophenol.....	-17.03	(88)
C <sub>6</sub> H <sub>6</sub>	Benzene.....	1.00	(127); 3
C <sub>6</sub> H <sub>6</sub>	<i>Benzene</i> .....	1.80	(127, 130); 3, 4
C <sub>6</sub> H <sub>6</sub> O	<i>Phenol</i> .....	-16.7	(127)
C <sub>6</sub> H <sub>7</sub> N	Aniline.....	0	(127)
C <sub>6</sub> H <sub>7</sub> N	<i>Aniline</i> .....	- 1.3	(127)
C <sub>6</sub> H <sub>10</sub>	Cyclohexene.....		3
C <sub>6</sub> H <sub>12</sub>	Cyclohexane.....		3
C <sub>6</sub> H <sub>12</sub> O <sub>2</sub>	Paraldehyde.....		3
C <sub>7</sub> H <sub>6</sub> O <sub>2</sub>	Benzoic acid.....	-13.4	(127)
C <sub>7</sub> H <sub>8</sub>	Toluene.....		3
C <sub>7</sub> H <sub>9</sub> N	<i>p</i> -Toluidine (23°).....	-14.61	(122)
C <sub>7</sub> H <sub>9</sub> NO <sub>2</sub>	Pyridine acetate.....	5.047	(109)
C <sub>7</sub> H <sub>16</sub>	Heptane.....	3.06	(127)
C <sub>8</sub> H <sub>9</sub> NO	Acetanilide (25°).....	-18.4	(122)
C <sub>8</sub> H <sub>10</sub>	<i>p</i> -Xylene.....		3
C <sub>8</sub> H <sub>18</sub>	Octane.....	- 2.34	(127)
C <sub>10</sub> H <sub>7</sub> NO <sub>2</sub>	Nitronaphthalene.....	-17.45	(88)
C <sub>10</sub> H <sub>8</sub>	Naphthalene (23°).....	-16.11	(122)
C <sub>12</sub> H <sub>10</sub>	Acenaphthene (21°).....	-18.8	(122)

CH<sub>4</sub>N<sub>2</sub>O, Urea

C <sub>2</sub> H <sub>6</sub> O	Ethyl alcohol (24°).....	-15.11	(122)
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CH<sub>2</sub>O<sub>2</sub>, Formic acid

C <sub>2</sub> H <sub>4</sub> O <sub>2</sub>	Acetic acid.....		3
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CH<sub>4</sub>O, Methyl alcohol

C <sub>2</sub> H <sub>2</sub> O <sub>4</sub>	Oxalic acid.....	- 3.64	(126)
C <sub>2</sub> H <sub>2</sub> O <sub>4</sub>	Oxalic acid (2H <sub>2</sub> O).....	-21.8	(126)
C <sub>2</sub> H <sub>4</sub> O <sub>2</sub>	Acetic acid.....	0	(127)
C <sub>2</sub> H <sub>4</sub> O <sub>2</sub>	Acetic acid.....	0.79	(127)
C <sub>2</sub> H <sub>6</sub> O	Ethyl alcohol.....		3, 4
C <sub>3</sub> H <sub>6</sub> O	Acetone.....	- 2.09	(127); 3
C <sub>3</sub> H <sub>7</sub> NO <sub>2</sub>	Urethane (24°).....	-18.20	(122)
C <sub>3</sub> H <sub>8</sub> O	n-Propyl alcohol.....		3, 4
C <sub>3</sub> H <sub>8</sub> O	Isopropyl alcohol.....		3
C <sub>4</sub> H <sub>8</sub> O <sub>2</sub>	Ethyl acetate.....	- 5.44	(127)
C <sub>4</sub> H <sub>8</sub> O <sub>2</sub>	Ethyl acetate.....	- 3.10	(127)
C <sub>4</sub> H <sub>10</sub> O	Ethyl ether.....	- 2.5	(127); 3
C <sub>4</sub> H <sub>10</sub> O	Isobutyl alcohol.....		3
C <sub>5</sub> H <sub>5</sub> N	Pyridine.....	2.30	(127)
C <sub>5</sub> H <sub>5</sub> N	Pyridine.....	4.19	(127)
C <sub>5</sub> H <sub>12</sub> O	Isoamyl alcohol.....		3
C <sub>6</sub> H <sub>5</sub> NO <sub>2</sub>	o-Nitrophenol.....	-20.1	(127)
C <sub>6</sub> H <sub>6</sub>	Benzene.....	-11.7	(127)
C <sub>6</sub> H <sub>6</sub>	Benzene.....	- 1.51	(127); 4
C <sub>6</sub> H <sub>6</sub> O <sub>2</sub>	Resorcinol.....	0.84	(127)



TABLE 2.—(Continued)

B-Component		Q	Lit. and Table No.*
Formula	Name (and temp., °C)		
CH <sub>4</sub> O.—(Continued)			
C <sub>6</sub> H <sub>7</sub> N	Aniline.....	0.08	(127); 3
C <sub>6</sub> H <sub>7</sub> N	Aniline.....	2.85	(127)
C <sub>7</sub> H <sub>5</sub> NO <sub>4</sub>	<i>o</i> -Nitrobenzoic acid.....	-17.2	(127)
C <sub>7</sub> H <sub>5</sub> NO <sub>4</sub>	<i>m</i> -Nitrobenzoic acid.....	-15.1	(127)
C <sub>7</sub> H <sub>5</sub> O <sub>2</sub>	Benzoic acid (13°).....	-12.1	(126, 127)
C <sub>7</sub> H <sub>5</sub> O <sub>2</sub>	Salicylic acid.....	-13.0	(126, 127)
C <sub>7</sub> H <sub>5</sub> O <sub>2</sub>	<i>m</i> -Hydroxybenzoic acid.....	-8.79	(127)
C <sub>7</sub> H <sub>7</sub> NO <sub>2</sub>	<i>o</i> -Aminobenzoic acid.....	-12.6	(127)
C <sub>7</sub> H <sub>7</sub> NO <sub>2</sub>	<i>m</i> -Aminobenzoic acid.....	-19.7	(127)
C <sub>7</sub> H <sub>7</sub> NO <sub>2</sub>	<i>p</i> -Aminobenzoic acid.....	-9.21	(127)
C <sub>7</sub> H <sub>8</sub>	Toluene.....	-4.60	(127)
C <sub>7</sub> H <sub>16</sub>	Heptane.....	-9.63	(127)
C <sub>7</sub> H <sub>16</sub>	Heptane.....	-4.65	(127)
C <sub>8</sub> H <sub>9</sub> NO	Acetanilide (24°).....	-18.8	(122)
C <sub>9</sub> H <sub>9</sub> O <sub>2</sub>	Cinnamic acid (13°).....	-15.9	(126)
C <sub>10</sub> H <sub>8</sub>	Naphthalene (24°).....	-17.70	(122)
C <sub>12</sub> H <sub>10</sub>	Acenaphthene (24°).....	-25.9	(122)
C <sub>12</sub> H <sub>24</sub> O <sub>2</sub>	Lauric acid.....	-41.4	(127)
C <sub>14</sub> H <sub>28</sub> O <sub>2</sub>	Myristic acid.....	-51.06	(127)
C <sub>16</sub> H <sub>32</sub> O <sub>2</sub>	Palmitic acid.....	-61.52	(127)
C <sub>19</sub> H <sub>16</sub>	Triphenylmethane.....	-24.6	(127)
C <sub>2</sub> H <sub>2</sub> O <sub>4</sub> , Oxalic acid			
C <sub>2</sub> H <sub>6</sub> O	Ethyl alcohol.....	-5.31	(126)
C <sub>3</sub> H <sub>8</sub> O	Propyl alcohol.....	-7.87	(126)
C <sub>2</sub> H <sub>2</sub> O <sub>4</sub> .2H <sub>2</sub> O, Oxalic acid			
C <sub>2</sub> H <sub>6</sub> O	Ethyl alcohol.....	-23.4	(126)
C <sub>3</sub> H <sub>8</sub> O	Propyl alcohol.....	-27.6	(126)
C <sub>2</sub> H <sub>3</sub> Cl <sub>3</sub> O <sub>2</sub> , Chloral hydrate			
C <sub>2</sub> H <sub>6</sub> O	Ethyl alcohol (24°).....	-4.73	(88, 122)
C <sub>3</sub> H <sub>6</sub> O	Acetone.....	-2.89	(88)
C <sub>4</sub> H <sub>10</sub> O	Ethyl ether.....	0	(88)
C <sub>7</sub> H <sub>8</sub>	Toluene (24°).....	-31.4	(122)
C <sub>2</sub> H <sub>4</sub> Br <sub>2</sub> , Ethylene bromide			
C <sub>2</sub> H <sub>4</sub> Cl <sub>2</sub>	Ethylene chloride.....		3
C <sub>2</sub> H <sub>4</sub> O <sub>2</sub>	Acetic acid.....		5
C <sub>2</sub> H <sub>4</sub> O <sub>2</sub>	Acetic acid.....		5
C <sub>6</sub> H <sub>5</sub> Cl	Chlorobenzene.....		3
C <sub>6</sub> H <sub>6</sub>	Benzene.....		3
C <sub>6</sub> H <sub>10</sub>	Cyclohexene.....		3
C <sub>6</sub> H <sub>12</sub>	Cyclohexane.....		3
C <sub>6</sub> H <sub>14</sub>	<i>n</i> -Hexane.....		3
C <sub>7</sub> H <sub>8</sub>	Toluene.....		3
C <sub>8</sub> H <sub>10</sub>	<i>p</i> -Xylene.....		3
C <sub>8</sub> H <sub>12</sub>	Mesitylene.....		3
C <sub>10</sub> H <sub>14</sub>	<i>p</i> -Cymene.....		3
C <sub>2</sub> H <sub>4</sub> Cl <sub>2</sub> , Ethylene chloride			
C <sub>6</sub> H <sub>6</sub>	Benzene.....		3
C <sub>7</sub> H <sub>8</sub>	Toluene.....		3
C <sub>2</sub> H <sub>4</sub> O, Acetaldehyde			
C <sub>2</sub> H <sub>6</sub> O	Ethyl alcohol.....		3
C <sub>4</sub> H <sub>10</sub> O	Ethyl ether.....		3
C <sub>2</sub> H <sub>4</sub> O <sub>2</sub> , Acetic acid			
C <sub>2</sub> H <sub>6</sub> O	Ethyl alcohol.....	-1.05	(7)
C <sub>2</sub> H <sub>6</sub> O	Ethyl alcohol.....	-2.01	(127)
C <sub>3</sub> H <sub>6</sub> O	Acetone.....	1.38	(127)
C <sub>3</sub> H <sub>6</sub> O	Acetone.....	0.84	(127)
C <sub>3</sub> H <sub>5</sub> O <sub>2</sub>	Lactic acid.....		3
C <sub>3</sub> H <sub>8</sub> O	Propyl alcohol.....	-1.42	(127)

\* The numbers not in parentheses are numbers of other tables in this section which should be consulted for further data.

TABLE 2.—(Continued)

B-Component		Q	Lit. and Table No.*
Formula	Name (and temp., °C)		
C <sub>2</sub> H <sub>4</sub> O <sub>2</sub> .—(Continued)			
C <sub>3</sub> H <sub>8</sub> O	Propyl alcohol.....	— 3.06	(127)
C <sub>4</sub> H <sub>8</sub> O <sub>2</sub>	Isobutyric acid.....		3
C <sub>4</sub> H <sub>8</sub> O <sub>2</sub>	Ethyl acetate.....	0.54	(127)
C <sub>4</sub> H <sub>10</sub> O	Ethyl ether.....	1.67	(127)
C <sub>4</sub> H <sub>10</sub> O	Isobutyl alcohol.....	— 2.76	(127)
C <sub>5</sub> H <sub>7</sub> N	Pyridine.....	27.2	(127)
C <sub>6</sub> H <sub>6</sub>	Benzene.....	— 1.88	(127); 5
C <sub>6</sub> H <sub>6</sub>	Benzene.....	— 2.26	(127); 3, 4, 5
C <sub>6</sub> H <sub>6</sub> O	Phenol.....	—10.00	(88)
C <sub>6</sub> H <sub>12</sub>	Cyclohexane.....		3
C <sub>6</sub> H <sub>7</sub> N	Aniline.....	28.9	(127)
C <sub>7</sub> H <sub>8</sub>	Toluene.....	— 1.3	(4, 1°7); 3
C <sub>7</sub> H <sub>16</sub>	Heptane.....	— 5.40	(127)
C <sub>10</sub> H <sub>8</sub>	Naphthalene.....	—17.45	(88)
C <sub>2</sub> H <sub>5</sub> NO, Acetamide			
C <sub>2</sub> H <sub>6</sub> O	Ethyl alcohol (23°).....	—15.11	(122)
C <sub>2</sub> H <sub>6</sub> O, Ethyl alcohol			
C <sub>3</sub> H <sub>6</sub> O	Acetone.....	— 5.11	(127); 3
C <sub>3</sub> H <sub>7</sub> NO <sub>2</sub>	Urethane (21°).....	—19.80	(122)
C <sub>3</sub> H <sub>8</sub> O	<i>n</i> -Propyl alcohol.....		3, 4
C <sub>3</sub> H <sub>8</sub> O <sub>2</sub>	Glycerol (24°).....	— 3.18	(88)
C <sub>4</sub> H <sub>8</sub> NO <sub>2</sub>	Succinimide (22°).....	—22.85	(122)
C <sub>4</sub> H <sub>8</sub> O <sub>2</sub>	Ethyl acetate.....	— 7.53	(127)
C <sub>4</sub> H <sub>8</sub> O <sub>2</sub>	Ethyl acetate.....	— 4.81	(127); 3
C <sub>4</sub> H <sub>10</sub> O	Ethyl ether.....	— 3.8	(127); 3
C <sub>4</sub> H <sub>10</sub> O	Isobutyl alcohol.....		3
C <sub>5</sub> H <sub>7</sub> N	Pyridine.....	0.54	(127)
C <sub>5</sub> H <sub>7</sub> N	Pyridine.....	2.26	(127)
C <sub>5</sub> H <sub>12</sub> O	Isoamyl alcohol.....		3
C <sub>6</sub> H <sub>4</sub> N <sub>2</sub> O <sub>4</sub>	<i>m</i> -Dinitrobenzene.....	—17.66	(88)
C <sub>6</sub> H <sub>6</sub>	Benzene.....	—16.7	(127); 4
C <sub>6</sub> H <sub>6</sub>	Benzene.....	— 1.51	(127); 3, 5
C <sub>6</sub> H <sub>6</sub> O	Phenol.....	— 2.5	(88, 127)
C <sub>6</sub> H <sub>6</sub> O <sub>2</sub>	Resorcinol (23°).....	2.89	(88, 122, 127)
C <sub>6</sub> H <sub>6</sub> O <sub>2</sub>	Pyrogallol.....	3.60	(88)
C <sub>6</sub> H <sub>7</sub> N	Aniline.....	— 2.26	(127)
C <sub>6</sub> H <sub>7</sub> N	Aniline.....	1.00	(127)
C <sub>6</sub> H <sub>8</sub> O <sub>7</sub>	Citric acid.....	—17.87	(88)
C <sub>6</sub> H <sub>15</sub> O <sub>4</sub> P	Triethyl phosphate.....	— 0.8	(52)
C <sub>7</sub> H <sub>5</sub> NO <sub>4</sub>	<i>m</i> -Nitrobenzoic acid.....	—12.1	(127)
C <sub>7</sub> H <sub>5</sub> O <sub>2</sub>	Benzoic acid.....	—12.6	(126, 127)
C <sub>7</sub> H <sub>5</sub> O <sub>2</sub>	Salicylic acid.....	—11.3	(126, 127)
C <sub>7</sub> H <sub>5</sub> O <sub>2</sub>	<i>m</i> -Hydroxybenzoic acid.....	— 6.70	(127)
C <sub>7</sub> H <sub>7</sub> NO	Benzamide (24°).....	—17.74	(122)
C <sub>7</sub> H <sub>7</sub> NO <sub>2</sub>	<i>o</i> -Aminobenzoic acid.....	—11.3	(127)
C <sub>7</sub> H <sub>7</sub> NO <sub>2</sub>	<i>m</i> -Aminobenzoic acid.....	—18.4	(127)
C <sub>7</sub> H <sub>7</sub> NO <sub>2</sub>	<i>p</i> -Aminobenzoic acid.....	— 7.53	(127)
C <sub>7</sub> H <sub>9</sub> N	<i>p</i> -Toluidine (24°).....	—15.28	(122)
C <sub>7</sub> H <sub>16</sub>	Heptane.....	— 3.3	(127)
C <sub>7</sub> H <sub>16</sub>	Heptane.....	— 2.64	(127)
C <sub>8</sub> H <sub>9</sub> NO	Acetanilide (23°).....	—17.6	(122)
C <sub>8</sub> H <sub>9</sub> O <sub>2</sub>	Cinnamic acid.....	—15.5	(126)
C <sub>10</sub> H <sub>8</sub>	Naphthalene (24°).....	—20.34	(88, 122, 127)
C <sub>10</sub> H <sub>14</sub> O	Thymol.....	— 8.79	(88)
C <sub>10</sub> H <sub>20</sub> O	Menthol.....	— 7.91	(88)
C <sub>12</sub> H <sub>10</sub>	Acenaphthene (24°).....	—24.7	(122)



TABLE 2.—(Continued)

B-Component		Q	Lit. and Table No.*
Formula	Name (and temp., °C)		
C <sub>2</sub> H <sub>6</sub> O.—(Continued)			
C <sub>12</sub> H <sub>10</sub>	Diphenyl.....	-17.79	(88)
C <sub>12</sub> H <sub>10</sub> N <sub>2</sub>	Azobenzene.....	-21.97	(88)
C <sub>12</sub> H <sub>24</sub> O <sub>2</sub>	Lauric acid.....	-40.6	(127)
C <sub>14</sub> H <sub>10</sub>	Phenanthrene (24°).....	-18.04	(122)
C <sub>22</sub> H <sub>42</sub> O <sub>2</sub>	Erucic acid.....	-56.08	(127)
C <sub>3</sub> H <sub>6</sub> O, Acetone			
C <sub>2</sub> H <sub>7</sub> NO <sub>2</sub>	Urethane.....	-15.86	(88)
C <sub>3</sub> H <sub>8</sub> O	Isopropyl alcohol.....		(112.5)
C <sub>4</sub> H <sub>8</sub> O <sub>2</sub>	Ethyl acetate.....	- 0.63	(127); 3
C <sub>4</sub> H <sub>10</sub> O	Ethyl ether.....		3
C <sub>6</sub> H <sub>5</sub> ClO	o-Chlorophenol.....		4
C <sub>6</sub> H <sub>6</sub>	Benzene.....	- 1.3	(127)
C <sub>6</sub> H <sub>6</sub>	Benzene.....	- 1.09	(127)
C <sub>6</sub> H <sub>6</sub> O	Phenol.....	- 0.59	(88)
C <sub>6</sub> H <sub>6</sub> O <sub>2</sub>	Resorcinol.....	4.19	(127)
C <sub>6</sub> H <sub>6</sub> O <sub>3</sub>	Pyrogallol.....	5.82	(88)
C <sub>6</sub> H <sub>7</sub> N	Aniline.....	5.44	(127)
C <sub>6</sub> H <sub>8</sub> O <sub>7</sub>	Citric acid.....	-13.4	(88)
C <sub>7</sub> H <sub>6</sub> O <sub>2</sub>	Benzoic acid.....	-12.1	(127)
C <sub>7</sub> H <sub>6</sub> O <sub>3</sub>	Salicylic acid.....	-10.9	(127)
C <sub>7</sub> H <sub>7</sub> NO <sub>2</sub>	Pyridine acetate.....	- 1.385	(109)
C <sub>7</sub> H <sub>16</sub>	Heptane.....	- 7.20	(127)
C <sub>10</sub> H <sub>7</sub> NO <sub>2</sub>	Nitronaphthalene.....	-29.17	(88)
C <sub>10</sub> H <sub>8</sub>	Naphthalene.....	-18.29	(88)
C <sub>10</sub> H <sub>9</sub> N	α-Naphthylamine.....	-10.84	(88)
C <sub>10</sub> H <sub>9</sub> N	β-Naphthylamine.....	-15.61	(88)
C <sub>12</sub> H <sub>10</sub>	Diphenyl.....	-18.71	(88)
C <sub>12</sub> H <sub>10</sub> N <sub>2</sub>	Azobenzene.....	-23.10	(88)
C <sub>12</sub> H <sub>11</sub> N	Diphenylamine.....	-13.52	(88)
C <sub>22</sub> H <sub>42</sub> O <sub>2</sub>	Erucic acid.....	-63.6	(127)
C <sub>3</sub> H <sub>8</sub> O <sub>2</sub> , Methyl acetate			
C <sub>4</sub> H <sub>8</sub> O <sub>2</sub>	Ethyl acetate.....		3, 4
C <sub>6</sub> H <sub>6</sub>	Benzene.....		4
C <sub>3</sub> H <sub>7</sub> NO <sub>2</sub> , Urethane			
C <sub>3</sub> H <sub>8</sub> O	Propyl alcohol (25°).....	-25.32	(122)
C <sub>7</sub> H <sub>8</sub>	Toluene (23°).....	-26.8	(122)
C <sub>3</sub> H <sub>8</sub> O, n-Propyl alcohol			
C <sub>4</sub> H <sub>8</sub> O <sub>2</sub>	Ethyl acetate.....	- 5.48	(127); 3
C <sub>4</sub> H <sub>10</sub> O	Ethyl ether.....		3
C <sub>4</sub> H <sub>10</sub> O	Isobutyl alcohol.....		3
C <sub>5</sub> H <sub>8</sub> N	Pyridine.....	0.17	(127)
C <sub>5</sub> H <sub>12</sub> O	Isoamyl alcohol.....		3
C <sub>6</sub> H <sub>6</sub>	Benzene.....	-14.6	(127)
C <sub>6</sub> H <sub>6</sub>	Benzene.....	- 2.26	(127); 4
C <sub>6</sub> H <sub>6</sub> O <sub>2</sub>	Resorcinol.....	- 0.84	(127)
C <sub>6</sub> H <sub>7</sub> N	Aniline.....	- 1.51	(127); 3
C <sub>7</sub> H <sub>5</sub> NO <sub>4</sub>	o-Nitrobenzoic acid.....	-20.9	(127)
C <sub>7</sub> H <sub>6</sub> O <sub>2</sub>	Benzoic acid.....	-14.2	(126, 127)
C <sub>7</sub> H <sub>6</sub> O <sub>3</sub>	Salicylic acid.....	-13.8	(126, 127)
C <sub>7</sub> H <sub>16</sub>	Heptane.....	- 9.21	(127)
C <sub>7</sub> H <sub>16</sub>	Heptane.....	- 1.63	(127)
C <sub>8</sub> H <sub>8</sub> O <sub>2</sub>	Cinnamic acid (13°).....	-15.9	(126)
C <sub>10</sub> H <sub>8</sub>	Naphthalene.....	-20.5	(122, 127)
C <sub>12</sub> H <sub>10</sub>	Acenaphthene (13°).....	-28.50	(122)
C <sub>12</sub> H <sub>24</sub> O <sub>2</sub>	Lauric acid.....	-40.2	(127)

\* The numbers not in parentheses are numbers of other tables in this section which should be consulted for further data.

TABLE 2.—(Continued)

B-Component		Q	Lit. and Table No.*
Formula	Name (and temp., °C)		
C <sub>4</sub> H <sub>5</sub> Cl <sub>3</sub> O <sub>2</sub> , Ethyl trichloroacetate			
C <sub>4</sub> H <sub>8</sub> O <sub>2</sub>	Ethyl acetate.....		3
C <sub>4</sub> H <sub>8</sub> O <sub>2</sub> , Ethyl acetate			
C <sub>4</sub> H <sub>10</sub> O	Ethyl ether.....		3, 4
C <sub>4</sub> H <sub>10</sub> O	Isobutyl alcohol.....	- 6.70	(127); 3
C <sub>5</sub> H <sub>5</sub> N	Pyridine.....	- 0.25	(127)
C <sub>5</sub> H <sub>12</sub> O	Isoamyl alcohol.....		3
C <sub>6</sub> H <sub>4</sub> N <sub>2</sub> O <sub>4</sub>	m-Dinitrobenzene.....	14.790	(56)
C <sub>6</sub> H <sub>6</sub>	Benzene.....	- 0.67	(127); 3
C <sub>6</sub> H <sub>6</sub>	Benzene.....	- 0.59	(127); 4
C <sub>6</sub> H <sub>6</sub> O <sub>2</sub>	Resorcinol.....	1.3	(127)
C <sub>6</sub> H <sub>7</sub> N	Aniline.....	3.01	(127)
C <sub>6</sub> H <sub>12</sub> O <sub>2</sub>	Amyl formate.....		3
C <sub>7</sub> H <sub>5</sub> NO <sub>4</sub>	o-Nitrobenzoic acid.....	-13.4	(127)
C <sub>7</sub> H <sub>6</sub> O <sub>2</sub>	Benzoic acid.....	-13.0	(127)
C <sub>7</sub> H <sub>6</sub> O <sub>3</sub>	Salicylic acid.....	- 8.37	(127)
C <sub>7</sub> H <sub>6</sub> O <sub>3</sub>	m-Hydroxybenzoic acid....	- 7.95	(127)
C <sub>7</sub> H <sub>7</sub> NO <sub>2</sub>	Pyridine acetate.....	- 0.988	(109)
C <sub>7</sub> H <sub>14</sub> O <sub>2</sub>	Amyl acetate.....		3, 4
C <sub>7</sub> H <sub>16</sub>	Heptane.....	- 5.06	(127)
C <sub>7</sub> H <sub>16</sub>	Heptane.....	- 5.61	(127)
C <sub>9</sub> H <sub>10</sub> O <sub>2</sub>	Ethyl benzoate.....		3
C <sub>10</sub> H <sub>8</sub>	Naphthalene.....	-17.2	(127)
C <sub>12</sub> H <sub>22</sub> O <sub>2</sub>	Lauric acid.....	-41.0	(127)
C <sub>22</sub> H <sub>42</sub> O <sub>2</sub>	Erucic acid.....	-56.5	(127)
C <sub>4</sub> H <sub>9</sub> Cl, Isobutyl chloride			
C <sub>5</sub> H <sub>5</sub> N	Pyridine.....	1.3	(127)
C <sub>6</sub> H <sub>6</sub>	Benzene.....	- 0.96	(127)
C <sub>7</sub> H <sub>16</sub>	Heptane.....	- 2.01	(127)
C <sub>4</sub> H <sub>10</sub> O, Ethyl ether			
C <sub>4</sub> H <sub>10</sub> O	Isobutyl alcohol.....		3
C <sub>5</sub> H <sub>5</sub> N	Pyridine.....	- 0.84	(127)
C <sub>5</sub> H <sub>12</sub> O	Isoamyl alcohol.....		3
C <sub>6</sub> H <sub>4</sub> N <sub>2</sub> O <sub>4</sub>	m-Dinitrobenzene.....	-22.64	(88)
C <sub>6</sub> H <sub>5</sub> NO <sub>3</sub>	o-Nitrophenol.....	-17.6	(88)
C <sub>6</sub> H <sub>6</sub>	Benzene.....	- 0.42	(127); 4
C <sub>6</sub> H <sub>6</sub> O	Phenol.....	- 0.36	(88)
C <sub>6</sub> H <sub>6</sub> O <sub>3</sub>	Pyrogallol.....	- 1.7	(88)
C <sub>6</sub> H <sub>7</sub> N	Aniline.....		3
C <sub>6</sub> H <sub>12</sub> O <sub>3</sub>	Paraldehyde.....		3
C <sub>7</sub> H <sub>6</sub> O <sub>2</sub>	Benzoic acid.....	-10.0	(127)
C <sub>10</sub> H <sub>7</sub> NO <sub>2</sub>	Nitronaphthalene.....	-24.20	(88)
C <sub>10</sub> H <sub>8</sub>	Naphthalene.....	-20.30	(88)
C <sub>10</sub> H <sub>14</sub> O	Thymal.....	- 4.48	(88)
C <sub>10</sub> H <sub>20</sub> O	Menthol.....	-19.29	(88)
C <sub>12</sub> H <sub>10</sub> N <sub>2</sub>	Azobenzene.....	-20.67	(88)
C <sub>12</sub> H <sub>11</sub> N	Diphenylamine.....	-14.6	(88)
C <sub>4</sub> H <sub>10</sub> O, Isobutyl alcohol			
C <sub>5</sub> H <sub>12</sub> O	Isoamyl alcohol.....		3
C <sub>6</sub> H <sub>6</sub>	Benzene.....	- 3.18	(127)
C <sub>7</sub> H <sub>16</sub>	Heptane.....	- 1.7	(127)
C <sub>5</sub> H <sub>5</sub> N, Pyridine			
C <sub>6</sub> H <sub>5</sub> ClO	o-Chlorophenol.....		4
C <sub>6</sub> H <sub>5</sub> NO <sub>3</sub>	o-Nitrophenol.....	-10.0	(127)
C <sub>6</sub> H <sub>6</sub>	Benzene.....	0	(127)
C <sub>6</sub> H <sub>6</sub> O	Phenol.....	7.11	(127)
C <sub>6</sub> H <sub>6</sub> O <sub>2</sub>	Resorcinol.....	20.9	(127)
C <sub>7</sub> H <sub>5</sub> O	o-Cresol.....		4
C <sub>7</sub> H <sub>5</sub> O	m-Cresol.....		4



TABLE 2.—(Continued)

B-Component		Q	Lit. and Table No.*
Formula	Name (and temp., °C)		
C <sub>5</sub> H <sub>10</sub> O <sub>2</sub> , Propyl acetate			
C <sub>5</sub> H <sub>12</sub> O <sub>2</sub>	Amyl formate.....		3
C <sub>5</sub> H <sub>12</sub> O, Amyl alcohol			
C <sub>5</sub> H <sub>10</sub>	p-Xylene.....		4
C <sub>5</sub> H <sub>12</sub> O, Isoamyl alcohol			
C <sub>5</sub> H <sub>8</sub>	Benzene.....	- 2.9	(127)
C <sub>7</sub> H <sub>16</sub>	Heptane.....	- 1.3	(127)
C <sub>6</sub> H <sub>4</sub> N <sub>2</sub> O <sub>4</sub> , m-Dinitrobenzene			
C <sub>6</sub> H <sub>6</sub>	Benzene.....	-15.86	(88)
C <sub>6</sub> H <sub>5</sub> Br, Bromobenzene			
C <sub>6</sub> H <sub>5</sub> Cl	Chlorobenzene.....		3
C <sub>6</sub> H <sub>6</sub>	Benzene.....		3
C <sub>6</sub> H <sub>5</sub> Cl, Chlorobenzene			
C <sub>6</sub> H <sub>6</sub>	Benzene.....		(121)
C <sub>8</sub> H <sub>10</sub>	p-Xylene.....		3
C <sub>6</sub> H <sub>5</sub> ClO, o-Chlorophenol			
C <sub>8</sub> H <sub>11</sub> N	Dimethylaniline.....		4
C <sub>8</sub> H <sub>7</sub> N	Quinoline.....		4
C <sub>6</sub> H <sub>5</sub> NO <sub>2</sub> , Nitrobenzene			
C <sub>6</sub> H <sub>7</sub> N	Aniline.....		3
C <sub>7</sub> H <sub>9</sub> N	o-Toluidine.....		3
C <sub>8</sub> H <sub>11</sub> N	Dimethylaniline.....		3
C <sub>8</sub> H <sub>11</sub> N	Ethylaniline.....		3
C <sub>10</sub> H <sub>15</sub> N	Diethylaniline.....		3
C <sub>6</sub> H <sub>5</sub> NO <sub>2</sub> , o-Nitrophenol			
C <sub>6</sub> H <sub>6</sub>	Benzene.....	-20.9	(88, 127)
C <sub>7</sub> H <sub>14</sub> O <sub>2</sub>	Isoamyl acetate.....	-14.73	(88)
C <sub>6</sub> H <sub>6</sub> , Benzene			
C <sub>6</sub> H <sub>6</sub> O	Phenol.....	-18.41	(88, 127)
C <sub>6</sub> H <sub>6</sub> O <sub>2</sub>	Resorcinol.....	-15.78	(88)
C <sub>6</sub> H <sub>7</sub> N	Aniline.....	- 2.51	(127)
C <sub>6</sub> H <sub>7</sub> N	Aniline.....	- 4.85	(127)
C <sub>6</sub> H <sub>12</sub>	Cyclohexane.....		3
C <sub>6</sub> H <sub>14</sub>	n-Hexane.....		3
C <sub>7</sub> H <sub>6</sub> O <sub>2</sub>	Benzoic acid.....	-14.2	(127)
C <sub>7</sub> H <sub>6</sub> O <sub>2</sub>	Salicylic acid.....	-23.9	(127)
C <sub>7</sub> H <sub>8</sub>	Toluene.....		3, 4
C <sub>7</sub> H <sub>8</sub> O	m-Cresol.....		3
C <sub>7</sub> H <sub>8</sub> NO <sub>2</sub>	Pyridine acetate.....	- 0.866	(109)
C <sub>7</sub> H <sub>16</sub>	Heptane.....	- 2.89	(127)
C <sub>7</sub> H <sub>16</sub>	Heptane.....	- 4.39	(127)
C <sub>8</sub> H <sub>10</sub>	m-Xylene.....		3
C <sub>8</sub> H <sub>18</sub>	Octane.....	- 2.9	(127)
C <sub>10</sub> H <sub>7</sub> NO <sub>2</sub>	Nitronaphthalene.....	-22.52	(88)
C <sub>10</sub> H <sub>8</sub>	Naphthalene.....	-18.50	(88, 127)
C <sub>10</sub> H <sub>14</sub> O	Thymol.....	-23.8	(88, 127)
C <sub>10</sub> H <sub>16</sub>	Pinene.....		3
C <sub>10</sub> H <sub>20</sub> O	Menthol.....	-28.0	(88)
C <sub>12</sub> H <sub>10</sub>	Diphenyl.....	-18.0	(88)
C <sub>12</sub> H <sub>10</sub> N <sub>2</sub>	Azobenzene.....	-21.18	(88)
C <sub>12</sub> H <sub>11</sub> N	Diphenylamine.....	-16.99	(88)
C <sub>12</sub> H <sub>24</sub> O <sub>2</sub>	Lauric acid.....	-40.6	(127)
C <sub>14</sub> H <sub>28</sub> O <sub>2</sub>	Myristic acid.....	-50.2	(127)
C <sub>16</sub> H <sub>32</sub> O <sub>2</sub>	Palmitic acid.....	-59.0	(127)
C <sub>18</sub> H <sub>16</sub>	Triphenylmethane.....	-17.6	(127)
C <sub>22</sub> H <sub>42</sub> O <sub>2</sub>	Erucic acid.....	-56.5	(127)

\* The numbers not in parentheses are numbers of other tables in this section which should be consulted for further data.

TABLE 2.—(Continued)

B-Component		Q	Lit. and Table No.*
Formula	Name (and temp., °C)		
C <sub>6</sub> H <sub>6</sub> O, Phenol			
C <sub>6</sub> H <sub>7</sub> N	Aniline.....		(103)
C <sub>6</sub> H <sub>6</sub> O <sub>2</sub> , Pyrogallol			
C <sub>6</sub> H <sub>7</sub> N	Aniline.....	11.51	(88)
C <sub>7</sub> H <sub>14</sub> O <sub>2</sub>	Amyl acetate.....	0	(88)
C <sub>6</sub> H <sub>7</sub> N, Aniline			
C <sub>6</sub> H <sub>14</sub>	Hexane.....		(99)
C <sub>7</sub> H <sub>16</sub>	Heptane.....	-10.17	(127)
C <sub>8</sub> H <sub>10</sub>	p-Xylene.....		4
C <sub>10</sub> H <sub>7</sub> NO <sub>2</sub>	Nitronaphthalene.....	-17.54	(88)
C <sub>10</sub> H <sub>8</sub>	Naphthalene.....	-19.80	(88)
C <sub>6</sub> H <sub>12</sub> , Cyclohexane			
C <sub>6</sub> H <sub>14</sub>	n-Hexane.....		3
C <sub>7</sub> H <sub>8</sub>	Toluene.....		3
C <sub>8</sub> H <sub>10</sub>	p-Xylene.....		3
C <sub>7</sub> H <sub>6</sub> O <sub>2</sub> , Benzoic acid			
C <sub>7</sub> H <sub>8</sub>	Toluene.....	-14.2	(127)
C <sub>7</sub> H <sub>8</sub> , Toluene			
C <sub>7</sub> H <sub>8</sub> O	m-Cresol.....		3
C <sub>7</sub> H <sub>16</sub>	Heptane.....	- 2.26	(127)
C <sub>8</sub> H <sub>10</sub>	p-Xylene.....		3
C <sub>10</sub> H <sub>8</sub>	Naphthalene (23°).....	-17.87	(122)
C <sub>12</sub> H <sub>10</sub>	Acenaphthene(23°).....	-20.05	(122)
C <sub>12</sub> H <sub>24</sub> O <sub>2</sub>	Lauric acid.....	-38.1	(127)
C <sub>18</sub> H <sub>16</sub>	Triphenylmethane.....	-17.2	(127)
C <sub>7</sub> H <sub>8</sub> O, m-Cresol			
C <sub>7</sub> H <sub>9</sub> N	o-Toluidine.....		3
C <sub>8</sub> H <sub>11</sub> N	Dimethylaniline.....		3
C <sub>7</sub> H <sub>14</sub> O <sub>2</sub> , Amyl acetate			
C <sub>10</sub> H <sub>7</sub> NO <sub>2</sub>	Nitronaphthalene.....	-18.75	(88)
C <sub>12</sub> H <sub>10</sub> N <sub>2</sub>	Azobenzene.....	-20.67	(88)
C <sub>12</sub> H <sub>11</sub> N	Diphenylamine.....	-14.86	(88)
C <sub>8</sub> H <sub>10</sub> , o-Xylene			
C <sub>8</sub> H <sub>10</sub>	m-Xylene.....		3
C <sub>8</sub> H <sub>10</sub>	p-Xylene.....		3
C <sub>8</sub> H <sub>10</sub> , m-Xylene			
C <sub>8</sub> H <sub>10</sub>	p-Xylene.....		3
C <sub>8</sub> H <sub>11</sub> N	Dimethylaniline.....		3

TABLE 3

The concentration is expressed by  $x_A$ , the mole fraction of the A-component in the mixture. Q is expressed in kilojoules evolved per mole mixture. The temperature is between 15 and 20° unless otherwise indicated.

<b>H<sub>2</sub>O</b>		<b>B = C<sub>2</sub>H<sub>6</sub>O<sub>2</sub>—</b>		<b>B = C<sub>2</sub>H<sub>6</sub>O<sub>2</sub>—</b>	
<b>B = C<sub>2</sub>H<sub>6</sub>O (51)</b>		<b>(Continued)</b>		<b>(Continued)</b>	
Ethyl alcohol		$x_A$	Q	$x_A$	Q
0.640	77°	0.4	0.6349	0.4	0.5311
0.843	79.2°	0.5	0.7286	0.5	0.6148
		0.6	0.7713	0.6	0.6696
		0.7	0.7433	0.7	0.6725
		0.8	0.7110	0.8	0.6457
		0.9	0.519	0.9	0.429
<b>B = C<sub>2</sub>H<sub>6</sub>O<sub>2</sub> (119)</b>		<b>t = 32°</b>		<b>t = 55°</b>	
Glycol					
$x_A$	Q				
0.1	0.175	0.1	0.147	0.1	0.136
0.2	0.349	0.2	0.295	0.2	0.271
0.3	0.423	0.3	0.357	0.3	0.328



<b>B = C<sub>2</sub>H<sub>5</sub>O<sub>2</sub>—</b> (Continued)		<b>B = C<sub>6</sub>H<sub>6</sub>—(Cont'd)</b>		<b>B = C<sub>4</sub>H<sub>10</sub>O—</b> (Continued)		<b>B = C<sub>2</sub>H<sub>4</sub>O (94.1)</b> Acetaldehyde <i>t</i> = 25°		<b>B = C<sub>4</sub>H<sub>10</sub>O (94.1)</b> Ethyl ether <i>t</i> = 25°		<b>B = C<sub>6</sub>H<sub>12</sub>O<sub>2</sub> (94.1)</b> Paraldehyde <i>t</i> = 25°					
<i>x<sub>A</sub></i>	<i>Q</i>	<i>x<sub>A</sub></i>	<i>Q</i>	<i>x<sub>A</sub></i>	<i>Q</i>	<i>x<sub>A</sub></i>	<i>Q</i>	<i>x<sub>A</sub></i>	<i>Q</i>	<i>x<sub>A</sub></i>	<i>Q</i>				
0.4	0.4838	0.443	-0.110	0.7305	-0.397	0.2125	0.652	0.1819	1.445	0.2406	1.349				
0.5	0.5574	0.507	-0.111	0.7703	-0.358	0.2562	0.782	0.3627	2.405	0.3982	1.988				
0.6	0.6056	0.538	-0.106	0.9246	-0.157	0.3833	1.058	0.4805	2.701	0.4981	2.231				
0.7	0.6211	0.636	-0.098	<b>B = C<sub>6</sub>H<sub>6</sub> (94.1, 118)</b> <i>t</i> = 25°		0.4144	1.109	0.5031	2.708	0.5916	2.311				
0.8	0.5867	0.764	-0.072	0.2020	-0.338	0.4348	1.121	0.5243	2.714	0.6996	2.142				
0.9	0.397	<b>B̄ = C<sub>6</sub>H<sub>7</sub>N (94)</b> Aniline <i>t</i> = 25°		0.5224	-0.565	0.5787	1.208	0.5841	2.599	0.8519	1.373				
0.1	0.136	0.0942	-0.408	0.6229	-0.541	0.6759	1.133	0.6563	2.402	0.9428	0.611				
0.2	0.271	0.1848	-0.707	0.7259	-0.465	0.7226	1.076	0.7516	1.915	<b>B = C<sub>7</sub>H<sub>8</sub> (5)</b> Toluene					
0.3	0.329	0.3005	-0.991	0.8384	-0.339	<b>B = C<sub>2</sub>H<sub>5</sub>O (94.1)</b> Ethyl alcohol <i>t</i> = 25°		<b>B = C<sub>4</sub>H<sub>10</sub>O (94.1)</b> Isobutyl alcohol <i>t</i> = 25°		0.075	0.184				
0.4	0.4708	0.4152	-1.181	0.9025	-0.227	0.1216	0.508	0.0586	0.080	0.260	0.5374				
0.5	0.5311	0.4827	-1.218	<b>B = C<sub>6</sub>H<sub>12</sub>O<sub>2</sub> (94.1)</b> Paraldehyde <i>t</i> = 25°		0.1765	0.644	0.0822	+0.089	<b>B = C<sub>8</sub>H<sub>10</sub> (5)</b> <i>p</i> -Xylene					
0.6	0.5604	0.5504	-1.245	0.2974	-0.959	0.3175	0.624	0.1980	-0.015	0.097	0.285				
0.7	0.5796	0.6215	-1.209	0.3908	-1.126	0.3777	0.489	0.2804	-0.214	0.298	0.720				
0.8	0.5679	0.7175	-1.129	0.5498	-1.268	0.4770	0.246	0.5146	-0.743	0.425	0.875				
0.9	0.371	0.7888	-1.030	0.6365	-1.250	0.5716	+0.009	0.6103	-0.873	0.490	0.912				
<b>CCl<sub>4</sub></b> <b>B = CS<sub>2</sub> (94.1)</b> <i>t</i> = 25°		0.8627	-0.787	0.6972	-1.193	0.7470	-0.365	0.8225	-0.882	0.772	0.672				
0.0934	-0.127	0.9092	-0.623	0.8243	-0.916	0.8350	-0.457	0.9502	-0.455	0.856	0.473				
0.1425	-0.180	<b>B = C<sub>7</sub>H<sub>8</sub> (5)</b> Toluene		0.9082	-0.580	<b>B = C<sub>3</sub>H<sub>6</sub>O (51)</b> Acetone <i>x<sub>A</sub>, t</i>		<b>B = C<sub>6</sub>H<sub>12</sub>O (94.1)</b> Isoamyl alcohol <i>t</i> = 25°		<b>CH<sub>2</sub>O<sub>2</sub></b> Formic acid <b>B = C<sub>2</sub>H<sub>4</sub>O<sub>2</sub> (101, 104)</b> Acetic acid <i>t</i> = 25°					
0.2838	-0.276	0.216	0.0150	<b>B = C<sub>10</sub>H<sub>16</sub> (94.1)</b> Pinene <i>t</i> = 25°		0.262	57°	1.214	0.0129	0.102	0.50	0.303			
0.4001	-0.307	0.327	0.0193	0.2845	-0.264	0.359	59°	1.569	0.0789	0.157					
0.5393	-0.311	0.475	0.2578	0.4719	-0.367	0.614	62°	1.544	0.1972	+0.144					
0.6693	-0.264	<b>CS<sub>2</sub></b> <b>B = CHCl<sub>3</sub> (94.1)</b> <i>t</i> = 25°		0.6532	-0.379	<i>x<sub>A</sub></i>		0.3742	-0.139	0.4590	-0.336				
0.8153	-0.179	0.1897	-0.313	0.7353	-0.353	<i>t</i> = 25° (94.1)		0.4590	-0.336	0.5793	-0.556				
<b>B = CHCl<sub>3</sub> (94.1)</b> <i>t</i> = 25°		0.3492	-0.474	0.7976	-0.318	0.2481	1.167	0.7986	-0.752	0.9402	-0.483				
0.1150	-0.103	0.4046	-0.513	0.8998	-0.200	0.3967	1.715	0.9402	-0.483	<b>B = C<sub>6</sub>H<sub>5</sub>Cl (5)</b>					
0.2428	-0.176	0.5906	-0.534	0.9585	-0.095	0.4578	1.868	<b>B = C<sub>6</sub>H<sub>5</sub>Cl (5)</b>		0.204	0.102				
0.3623	-0.219	0.6720	-0.502	<b>CHBr<sub>3</sub></b> <b>B = C<sub>7</sub>H<sub>8</sub> (5)</b> Toluene		0.5004	1.921	0.339	0.149	0.4344	0.168				
0.4331	-0.228	0.8193	-0.352	0.067	0.082	0.5476	1.973	0.4344	0.168	0.561	0.1753				
0.5411	-0.226	0.9351	-0.143	0.238	0.248	0.6486	1.900	<b>B = C<sub>6</sub>H<sub>6</sub> (5)</b>		<b>B = C<sub>3</sub>H<sub>7</sub>O (94.1)</b> Acetone <i>t</i> = 25°					
0.7295	-0.185	<b>B = C<sub>2</sub>H<sub>4</sub>Br<sub>2</sub> (94.1)</b> Ethylene bromide <i>t</i> = 25°		0.444	0.326	0.6981	1.775	0.204	0.102	0.6110	-0.008				
0.8178	-0.146	0.1607	-0.378	0.780	0.223	0.7558	1.573	0.339	0.149	0.7082	-0.009				
<b>B = C<sub>2</sub>H<sub>4</sub>Br<sub>2</sub> (94.1)</b> Ethylene bromide <i>t</i> = 25°		0.3728	-0.693	0.940	0.075	0.9808	0.159	0.4344	0.168	<b>B = C<sub>3</sub>H<sub>7</sub>O (94.1)</b> Acetone <i>t</i> = 25°					
0.1146	-0.198	0.5184	-0.788	<b>CHCl<sub>3</sub></b> <b>B = CH<sub>3</sub>O (94.1)</b> Methyl alcohol <i>t</i> = 25°		<b>B = C<sub>3</sub>H<sub>7</sub>O (94.1)</b> <i>n</i> -Propyl alcohol <i>t</i> = 25°		0.561	0.1753	0.2426	-0.541				
0.2817	-0.406	0.5683	-0.792	0.1154	0.434	0.0486		0.212	0.339	0.149	0.4244	-0.686			
0.3733	-0.472	0.8300	-0.521	0.2041	0.594	0.1640		0.415	0.4344	0.168	0.5163	-0.671			
0.4835	-0.509	0.9206	-0.280	0.3001	0.607	0.2794		0.342	0.561	0.1753	0.5966	-0.635			
0.5404	-0.511	<b>B = C<sub>4</sub>H<sub>8</sub>O<sub>2</sub> (94.1)</b> Ethyl acetate <i>t</i> = 25°		0.4715	+0.349	0.3399		+0.244	0.561	0.1753	0.6014	-0.632			
0.7565	-0.414	0.2199	-0.729	0.6345	-0.014	0.5011		-0.131	0.561	0.1753	0.6870	-0.556			
0.8455	-0.274	0.4690	-1.123	0.6645	-0.080	0.5123		-0.151	0.561	0.1753	0.8067	-0.387			
<b>B = C<sub>4</sub>H<sub>8</sub>O<sub>2</sub> (51)</b> Ethyl acetate <i>t</i> = 74.8°		0.5249	-1.145	0.8042	-0.314	0.6823		-0.516	0.561	0.1753	0.9315	-0.149			
0.308	-0.259	0.6522	-1.112	0.9141	-0.393	0.7411		-0.587	0.561	0.1753	<b>B = C<sub>3</sub>H<sub>7</sub>O (94.1)</b> <i>n</i> -Propyl alcohol <i>t</i> = 25°				
<b>B = C<sub>6</sub>H<sub>6</sub> (94.1)</b> <i>t</i> = 25°		0.7578	-0.946	<b>B = C<sub>2</sub>H<sub>4</sub>Br<sub>2</sub> (94.1)</b> Ethylene bromide <i>t</i> = 25°		0.8347		-0.637	0.561	0.1753	0.4451	-0.091			
0.2996	-0.091	0.8119	-0.821	0.2991	0.087	0.9359		-0.449	0.561	0.1753	0.6666	-0.097			
0.3506	-0.106	0.9130	-0.468	0.4246	0.103	<b>B = C<sub>3</sub>H<sub>7</sub>O<sub>2</sub> (94.1)</b> Ethyl acetate <i>t</i> = 25°		0.561	0.1753	0.561	0.1753	0.7962	-0.074		
0.5012	-0.107	<b>B = C<sub>4</sub>H<sub>10</sub>O (94.1)</b> Ethyl ether <i>t</i> = 25°		0.5352	0.109	0.2145		1.109	0.561	0.1753	<b>B = C<sub>3</sub>H<sub>7</sub>O (101, 104)</b> Isopropyl alcohol <i>x<sub>A</sub>, t</i>				
0.6177	-0.104	0.1462	-0.200	0.6293	0.108	0.3766		1.748	0.561	0.1753	0.255	-0.5102			
0.7309	-0.089	0.3571	-0.396	0.8476	0.048	0.4581		1.967	0.561	0.1753	0.410	-0.6424			
0.8675	-0.054	0.4167	-0.436	0.8902	0.030	0.5850		2.034	0.561	0.1753	0.578	-0.6278			
<b>(5)</b>		0.6014	-0.456	<b>B = C<sub>3</sub>H<sub>7</sub>O (94.1)</b> Ethyl acetate <i>t</i> = 25°		0.6255		1.985	0.561	0.1753	0.696	-0.5487			
0.033	-0.013	<b>B = C<sub>3</sub>H<sub>7</sub>O (101, 104)</b> Isopropyl alcohol <i>x<sub>A</sub>, t</i>		<b>B = C<sub>3</sub>H<sub>7</sub>O (94.1)</b> Ethyl acetate <i>t</i> = 25°		0.6955		1.841	0.561	0.1753	0.873	-0.2942			
0.256	-0.086	<b>B = C<sub>3</sub>H<sub>7</sub>O (101, 104)</b> Isopropyl alcohol <i>x<sub>A</sub>, t</i>		<b>B = C<sub>3</sub>H<sub>7</sub>O (94.1)</b> Ethyl acetate <i>t</i> = 25°		0.7158		1.778	0.561	0.1753					
		<b>B = C<sub>3</sub>H<sub>7</sub>O (101, 104)</b> Isopropyl alcohol <i>x<sub>A</sub>, t</i>		<b>B = C<sub>3</sub>H<sub>7</sub>O (94.1)</b> Ethyl acetate <i>t</i> = 25°		0.9102		0.721	0.561	0.1753					



**CH<sub>4</sub>O.—(Cont'd)****B = C<sub>4</sub>H<sub>10</sub>O (94.1)**

Ethyl ether	
$x_A$	$Q$
$t = 25^\circ$	
0.2173	-0.414
0.3197	-0.502
0.5582	-0.410
0.6386	-0.336
0.7101	-0.257
0.8221	-0.153
0.9259	-0.049

**B = C<sub>4</sub>H<sub>10</sub>O (94.1)**

Isobutyl alcohol	
$x_A$	$Q$
$t = 25^\circ$	
0.5140	-0.170
0.7135	-0.165
0.8508	-0.116

**B = C<sub>5</sub>H<sub>12</sub>O (94.1)**

Isoamyl alcohol	
$x_A$	$Q$
$t = 25^\circ$	
0.5140	-0.191
0.7683	-0.187
0.8684	-0.132

**B = C<sub>6</sub>H<sub>7</sub>N (94)**

Aniline	
$x_A$	$Q$
$t = 25^\circ$	
0.0855	-0.018
0.1639	-0.016
0.2558	+0.015
0.3297	0.053
0.4359	0.116
0.5261	0.149
0.6205	0.187
0.7228	0.215
0.8172	0.208
0.8397	0.200
0.9362	0.121
0.9486	0.094

**C<sub>2</sub>H<sub>4</sub>Br<sub>2</sub>**

Ethylene bromide	
$x_A$	$Q$
$B = C_2H_4Cl_2$ (5)	
Ethylene chloride	
0.215	-0.123

**B = C<sub>6</sub>H<sub>5</sub>Cl (5)**

Chlorobenzene	
$x_A$	$Q$
0.070	-0.086
0.332	-0.286

**B = C<sub>6</sub>H<sub>6</sub> (5)**

Cyclohexene	
$x_A$	$Q$
0.054	-0.0590
0.186	-0.1762
0.364	-0.2624
0.535	-0.2888
0.648	-0.2616
0.821	-0.1728
0.946	-0.0590

**B = C<sub>6</sub>H<sub>10</sub> (5)**

Cyclohexane	
$x_A$	$Q$
0.107	-0.2440
0.296	-0.0544

**B = C<sub>6</sub>H<sub>12</sub> (5)**

Cyclohexane	
$x_A$	$Q$
0.098	-0.490
0.182	-0.841

**B = C<sub>6</sub>H<sub>12</sub>—****(Continued)**

$x_A$	$Q$
0.308	-1.184
0.375	-1.297
0.495	-1.381
0.529	-1.364
0.555	-1.360
0.687	-1.168
0.690	-1.168
0.765	-0.992
0.842	-0.741
0.949	-0.2745

**B = C<sub>6</sub>H<sub>14</sub> (5)**

<i>n</i> -Hexane	
$x_A$	$Q$
0.94	-0.4009

**B = C<sub>7</sub>H<sub>8</sub> (5)**

Toluene	
$x_A$	$Q$
0.078	+0.0732
0.250	-0.0121
0.450	-0.0691
0.567	-0.0975
0.710	-0.114
0.830	-0.109

**B = C<sub>8</sub>H<sub>10</sub> (5)**

<i>p</i> -Xylene	
$x_A$	$Q$
0.082	0.087
0.272	0.175
0.486	0.106
0.602	0.036
0.642	+0.010
0.722	-0.036
0.868	-0.0632
0.966	-0.029

**B = C<sub>9</sub>H<sub>12</sub> (5)**

Mesitylene	
$x_A$	$Q$
0.110	0.0737
0.350	+0.0360
0.486	-0.0636
0.638	-0.1331
0.749	-0.1632
0.878	-0.1163

**B = C<sub>10</sub>H<sub>14</sub> (5)**

<i>p</i> -Cymene	
$x_A$	$Q$
0.100	-0.00862
0.320	-0.0866
0.454	-0.1787
0.610	-0.2611
0.804	-0.297
0.900	-0.2335

**C<sub>2</sub>H<sub>4</sub>Cl<sub>2</sub>**

Ethylene chloride	
$x_A$	$Q$
0.74	-0.0732

**B = C<sub>7</sub>H<sub>8</sub> (5)**

Toluene	
$x_A$	$Q$
0.079	0.0427
0.262	0.0783
0.385	0.661
0.537	0.025
0.618	+0.0025
0.803	-0.0314
0.944	-0.0184

**C<sub>2</sub>H<sub>4</sub>O****Acetaldehyde****B = C<sub>2</sub>H<sub>6</sub>O (104.1)**

Ethyl alcohol	
$x_A$	$Q$
0.1621	-1.530
0.2475	-2.750
0.2709	-2.979
0.2910	-3.300
0.3059	-3.269
0.3422	-3.756
0.3906	-3.974
0.4211	-4.131
0.4244	-4.104
0.4422	-4.177
0.4973	-4.188
0.5114	-4.029
0.5285	-3.599
0.5470	-3.085
0.5812	-2.826
0.6478	-2.321
0.6717	-2.160
0.8110	-1.658

**B = C<sub>4</sub>H<sub>10</sub>O (94.1)**

Ethyl ether	
$x_A$	$Q$
$t = 25^\circ$	
0.3477	-0.523
0.5434	-0.565
0.6588	-0.515
0.7473	-0.428
0.8740	-0.250

**C<sub>2</sub>H<sub>4</sub>O<sub>2</sub>****Acetic acid****B = C<sub>2</sub>H<sub>6</sub>O<sub>3</sub> (104)****Lactic acid**

$x_A$	$Q$
0.5	0.258

**B = C<sub>4</sub>H<sub>8</sub>O<sub>2</sub> (104)**

Isobutyric acid	
$x_A$	$Q$
0.49	0.206

**B = C<sub>6</sub>H<sub>6</sub> (4)** **$t = 5.3^\circ$** 

$x_A$	$Q$
0.1528	-0.064
0.1765	-0.083
0.2120	-0.126
0.2500	-0.197
0.3289	-0.301

**B = C<sub>6</sub>H<sub>12</sub> (5)****Cyclohexane**

$x_A$	$Q$
0.2424	-1.2743
0.417	-1.5945
0.540	-1.4145
0.643	-1.5246
0.701	-1.4380
0.772	-1.197
0.825	-0.983

**B = C<sub>7</sub>H<sub>8</sub> (5)****Toluene**

$x_A$	$Q$
0.189	-0.2256
0.258	-0.2754
0.324	-0.3281
0.437	-0.368
0.482	-0.3729
0.537	-0.3720

**C<sub>2</sub>H<sub>6</sub>O****Ethyl alcohol****B = C<sub>2</sub>H<sub>6</sub>O (94.1)****Acetone** **$t = 25^\circ$** 

$x_A$	$Q$
0.1710	-0.705
0.3404	-1.055
0.4417	-1.123
0.5400	-1.117
0.5558	-1.117
0.6325	-1.050
0.7392	-0.879
0.8947	-0.444

**B = C<sub>3</sub>H<sub>8</sub>O*****n*-Propyl alcohol** **$t = 25^\circ$  (94.1)**

$x_A$	$Q$
0.3541	-0.023
0.6031	-0.027
0.8030	-0.021

 **$t = 25^\circ$  (113)**

$x_A$	$Q$
0.158	-0.013
0.303	-0.018
0.439	-0.020
0.566	-0.020
0.684	-0.017
0.796	-0.012
0.902	-0.007

**B = C<sub>4</sub>H<sub>8</sub>O<sub>2</sub> (94.1)****Ethyl acetate** **$t = 25^\circ$** 

$x_A$	$Q$
0.1932	-0.934
0.5346	-1.320
0.5445	-1.166?
0.5812	-1.216?
0.7077	-1.045
0.7776	-0.846
0.9051	-0.421

**B = C<sub>4</sub>H<sub>10</sub>O (94.1)****Ethyl ether** **$t = 25^\circ$** 

$x_A$	$Q$
0.0882	-0.382
0.2756	-0.668
0.4379	-0.677
0.5889	-0.569
0.6675	-0.478
0.7191	-0.434
0.8380	-0.254
0.9695	-0.040

**B = C<sub>4</sub>H<sub>10</sub>O (94.1)****Isobutyl alcohol** **$t = 25^\circ$** 

$x_A$	$Q$
0.3519	-0.050
0.5914	-0.064
0.7748	-0.046

**B = C<sub>5</sub>H<sub>12</sub>O (94.1)****Isoamyl alcohol** **$t = 25^\circ$** 

$x_A$	$Q$
0.3440	-0.057
0.6977	-0.067
0.8302	-0.058

**B = C<sub>6</sub>H<sub>6</sub> (51)** **$x_A, t$** 

$Q$
0.420   68.2°   -0.963
0.649   68.5°   -1.507
0.807   68.9°   -0.812

**C<sub>3</sub>H<sub>6</sub>O****Acetone****B = C<sub>4</sub>H<sub>8</sub>O<sub>2</sub> (94.1)****Ethyl acetate** **$t = 25^\circ$** 

$x_A$	$Q$
0.2062	-0.093
0.3237	-0.120
0.5046	-0.133
0.5965	-0.131
0.6644	-0.123
0.7535	-0.098
0.9128	-0.045

**B = C<sub>4</sub>H<sub>10</sub>O****Ethyl ether** **$t = 25^\circ$  (94.1, 117)**

$x_A$	$Q$
0.1155	0.249
0.2068	0.385
0.2943	0.461
0.4998	0.505
0.7270	0.385
0.8295	0.258
0.9077	0.159

 **$x_A, t$** 

$Q$ (51)
0.334   37.1°   -0.473
0.456   40°   -0.404
0.594   40.5°   -0.557
0.789   46.3°   -0.312

**C<sub>3</sub>H<sub>8</sub>O<sub>2</sub>****Methyl acetate****B = C<sub>4</sub>H<sub>8</sub>O<sub>2</sub>****Ethyl acetate****(101, 104)**

$x_A$	$Q$
0.50	0.052

**C<sub>3</sub>H<sub>8</sub>O*****n*-Propyl alcohol****B = C<sub>4</sub>H<sub>8</sub>O<sub>2</sub> (94.1)****Ethyl acetate** **$t = 25^\circ$** 

$x_A$	$Q$
0.1382	-0.852
0.2784	-1.318
0.4406	-1.521
0.4779	-1.523
0.4875	-1.511
0.6248	-1.406
0.7880	-0.990
0.9101	-0.509

**B = C<sub>4</sub>H<sub>10</sub>O (94.1)****Ethyl ether** **$t = 25^\circ$** 

$x_A$	<
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<b>B = C<sub>6</sub>H<sub>6</sub>.—</b> (Continued)		<b>C<sub>4</sub>H<sub>10</sub>O</b> Isobutyl alcohol <b>B = C<sub>6</sub>H<sub>12</sub>O (94.1)</b> Isoamyl alcohol		<b>C<sub>6</sub>H<sub>6</sub></b> <b>B = C<sub>6</sub>H<sub>12</sub> (5)</b> Cyclohexane		<b>B = C<sub>8</sub>H<sub>10</sub>.—</b> (Continued)		<b>B = C<sub>7</sub>H<sub>9</sub>N.—</b> (Continued)		<b>B = C<sub>8</sub>H<sub>10</sub>.—</b> (Continued)				
$x_A$	$Q$	$x_A$	$Q$	$x_A$	$Q$	$x_A$	$Q$	$x_A$	$Q$	$x_A$	$Q$			
0.6324	-0.094			0.097	-0.3013	0.767	-0.4369	0.25	20.4°	-1.590	0.269	0.0092		
0.7976	-0.075			0.670	-0.7140	0.920	-0.1954	0.25	88°	-1.193	0.729	0.0067		
0.8760	-0.040			0.752	-0.6068	<b>C<sub>7</sub>H<sub>8</sub></b>		0.50	22.1°	-2.469	<b>B = C<sub>8</sub>H<sub>10</sub></b>			
<b>B = C<sub>6</sub>H<sub>12</sub>O<sub>2</sub> (101, 104)</b>		$t = 25^\circ$		0.859	-0.4028	Toluene		0.50	55.9°	-2.072	<b>p-Xylene</b>			
Amyl formate		0.3349	-0.005	0.924	-0.2323	<b>B = C<sub>7</sub>H<sub>8</sub>O</b>		0.50	90.5°	-1.988	0.319		0.011	
0.50		0.5251	-0.006	<b>B = C<sub>6</sub>H<sub>14</sub> (5)</b>		<b>m-Cresol (101, 104)</b>		0.75	19.4°	-2.406	0.815		0.004	
0.036		0.7520	-0.015	<b>n-Hexane</b>		0.47		0.686	<b>B = C<sub>8</sub>H<sub>11</sub>N</b>		<b>C<sub>8</sub>H<sub>10</sub></b>			
<b>B = C<sub>7</sub>H<sub>14</sub>O<sub>2</sub> (101, 104)</b>		<b>C<sub>5</sub>H<sub>10</sub>O<sub>2</sub></b>		<b>B = C<sub>7</sub>H<sub>8</sub> (5)</b>		<b>B = C<sub>8</sub>H<sub>10</sub> (5)</b>		<b>Dimethylaniline</b>		<b>m-Xylene (101, 104)</b>				
Amyl acetate		Propyl acetate		Toluene		<b>p-Xylene</b>		0.50		16.3°	-0.144	<b>B = C<sub>8</sub>H<sub>10</sub></b>		
0.49		<b>B = C<sub>6</sub>H<sub>12</sub>O<sub>2</sub> (101, 104)</b>		0.579	-0.912	0.232		-0.00565	0.50		15.3°	-0.128	<b>p-Xylene</b>	
0.216		Amyl formate		0.687	-0.841	0.350		-0.0084	<b>C<sub>8</sub>H<sub>10</sub></b>		0.292		-0.0109	
<b>B = C<sub>6</sub>H<sub>10</sub>O<sub>2</sub> (101, 104)</b>		0.299		0.844	-0.5177	0.480		-0.0092	<b>o-Xylene (101, 104)</b>		0.754		-0.0013	
Ethyl benzoate		0.742		0.940	-0.2172	<b>C<sub>7</sub>H<sub>8</sub>O</b>		<b>B = C<sub>8</sub>H<sub>10</sub></b>		<b>B = C<sub>8</sub>H<sub>11</sub>N</b>		<b>Dimethylaniline</b>		
0.50		<b>C<sub>6</sub>H<sub>5</sub>Br</b>		<b>B = C<sub>7</sub>H<sub>8</sub>O (101, 102, 104)</b>		<b>m-Cresol (101, 104)</b>		<b>B = C<sub>8</sub>H<sub>10</sub></b>		0.287		0.011		
-0.227		Bromobenzene		0.54		0.866		<b>m-Xylene</b>		0.734		0.013		
<b>C<sub>4</sub>H<sub>10</sub>O</b>		<b>B = C<sub>6</sub>H<sub>5</sub>Cl (101, 104)</b>		<b>B = C<sub>7</sub>H<sub>8</sub>O (101, 102, 104)</b>		<b>m-Cresol</b>		<b>B = C<sub>8</sub>H<sub>10</sub>O<sub>2</sub>.—</b>		<b>CHCl<sub>3</sub>.—(Cont'd)</b>				
Ethyl ether		Chlorobenzene		<b>m-Cresol</b>		<b>B = C<sub>8</sub>H<sub>10</sub> (101, 104)</b>		(Continued)		% A		$Q$		
<b>B = C<sub>4</sub>H<sub>10</sub>O (94.1)</b>		0.212		<b>B = C<sub>8</sub>H<sub>10</sub> (101, 104)</b>		<b>m-Xylene</b>		% A		40		-6.40		
Isobutyl alcohol		0.674		<b>m-Xylene</b>		0.5		86.1		50		-6.65		
$t = 25^\circ$		<b>B = C<sub>6</sub>H<sub>5</sub>Cl</b>		0.5		0.239		90.2		60		-6.28		
0.1097		Chlorobenzene		<b>B = C<sub>10</sub>H<sub>16</sub> (94.1)</b>		<b>Pinene</b>		92.8		70		-5.27		
-0.266		<b>B = C<sub>6</sub>H<sub>5</sub>Cl</b>		Pinene		$t = 25^\circ$		96.2		80		-3.89		
-0.552		<b>B = C<sub>6</sub>H<sub>5</sub>Cl</b>		0.2128		-0.424		<b>CCl<sub>4</sub></b>		90		-2.22		
-0.732		<b>B = C<sub>6</sub>H<sub>5</sub>Cl</b>		0.4758		-0.739		<b>B = C<sub>6</sub>H<sub>6</sub> (118.2)</b>		<b>B = C<sub>7</sub>H<sub>8</sub> (118.2)</b>		<b>B = C<sub>7</sub>H<sub>8</sub>O (137)</b>		
-0.839		<b>B = C<sub>6</sub>H<sub>5</sub>Cl</b>		0.5399		-0.730		$t = 18^\circ$		<b>Toluene</b>		$t = 0^\circ$		
-0.867		<b>B = C<sub>6</sub>H<sub>5</sub>Cl</b>		0.6251		-0.725		10		-0.301		10		-2.948
-0.836		<b>B = C<sub>6</sub>H<sub>5</sub>Cl</b>		0.7634		-0.624		20		-0.598		20		-5.488
-0.549		<b>B = C<sub>6</sub>H<sub>5</sub>Cl</b>		0.8686		-0.470		30		-0.816		30		-7.483
-0.252		<b>B = C<sub>6</sub>H<sub>5</sub>Cl</b>		0.9382		-0.234		40		-0.963		40		-8.706
<b>B = C<sub>6</sub>H<sub>12</sub>O (94.1)</b>		<b>B = C<sub>6</sub>H<sub>5</sub>Cl</b>		<b>C<sub>6</sub>H<sub>12</sub></b>		<b>C<sub>6</sub>H<sub>12</sub></b>		50		-1.030		50		-9.203
Isoamyl alcohol		<b>B = C<sub>6</sub>H<sub>5</sub>Cl</b>		Cyclohexane		<b>B = C<sub>6</sub>H<sub>14</sub> (5)</b>		60		-1.030		60		-9.010
$t = 25^\circ$		<b>B = C<sub>6</sub>H<sub>5</sub>Cl</b>		<b>B = C<sub>6</sub>H<sub>14</sub> (5)</b>		<b>n-Hexane</b>		70		-0.912		70		-8.513
0.1245		<b>B = C<sub>6</sub>H<sub>5</sub>Cl</b>		<b>B = C<sub>7</sub>H<sub>8</sub> (5)</b>		0.75		80		-0.699		80		-6.910
-0.271		<b>B = C<sub>6</sub>H<sub>5</sub>Cl</b>		<b>B = C<sub>7</sub>H<sub>8</sub> (5)</b>		<b>B = C<sub>7</sub>H<sub>8</sub> (5)</b>		90		-0.452		80		-6.910
-0.592		<b>B = C<sub>6</sub>H<sub>5</sub>Cl</b>		<b>B = C<sub>7</sub>H<sub>8</sub> (5)</b>		<b>B = C<sub>7</sub>H<sub>8</sub> (5)</b>		<b>B = C<sub>7</sub>H<sub>8</sub>O<sub>2</sub>.—</b>		<b>CHCl<sub>3</sub>.—(Cont'd)</b>				
-0.699		<b>B = C<sub>6</sub>H<sub>5</sub>Cl</b>		<b>B = C<sub>7</sub>H<sub>8</sub> (5)</b>		<b>B = C<sub>7</sub>H<sub>8</sub> (5)</b>		(Continued)		% A		$Q$		
-0.770		<b>B = C<sub>6</sub>H<sub>5</sub>Cl</b>		<b>B = C<sub>7</sub>H<sub>8</sub> (5)</b>		<b>B = C<sub>7</sub>H<sub>8</sub> (5)</b>		% A		40		-6.40		
-0.776		<b>B = C<sub>6</sub>H<sub>5</sub>Cl</b>		<b>B = C<sub>7</sub>H<sub>8</sub> (5)</b>		<b>B = C<sub>7</sub>H<sub>8</sub> (5)</b>		86.1		50		-6.65		
-0.739		<b>B = C<sub>6</sub>H<sub>5</sub>Cl</b>		<b>B = C<sub>7</sub>H<sub>8</sub> (5)</b>		<b>B = C<sub>7</sub>H<sub>8</sub> (5)</b>		90.2		60		-6.28		
-0.603		<b>B = C<sub>6</sub>H<sub>5</sub>Cl</b>		<b>B = C<sub>7</sub>H<sub>8</sub> (5)</b>		<b>B = C<sub>7</sub>H<sub>8</sub> (5)</b>		92.8		70		-5.27		
-0.465		<b>B = C<sub>6</sub>H<sub>5</sub>Cl</b>		<b>B = C<sub>7</sub>H<sub>8</sub> (5)</b>		<b>B = C<sub>7</sub>H<sub>8</sub> (5)</b>		96.2		80		-3.89		
<b>B = C<sub>6</sub>H<sub>7</sub>N (94)</b>		<b>B = C<sub>6</sub>H<sub>5</sub>Cl</b>		<b>B = C<sub>7</sub>H<sub>8</sub> (5)</b>		<b>B = C<sub>7</sub>H<sub>8</sub> (5)</b>		<b>CCl<sub>4</sub></b>		<b>B = C<sub>7</sub>H<sub>8</sub> (118.2)</b>		<b>B = C<sub>7</sub>H<sub>8</sub>O (137)</b>		
Aniline		<b>B = C<sub>6</sub>H<sub>5</sub>Cl</b>		<b>B = C<sub>7</sub>H<sub>8</sub> (5)</b>		<b>B = C<sub>7</sub>H<sub>8</sub> (5)</b>		$t = 18^\circ$		<b>Toluene</b>		$t = 0^\circ$		
$t = 20^\circ$		<b>B = C<sub>6</sub>H<sub>5</sub>Cl</b>		<b>B = C<sub>7</sub>H<sub>8</sub> (5)</b>		<b>B = C<sub>7</sub>H<sub>8</sub> (5)</b>		10		-0.301		10		-2.948
0.1031		<b>B = C<sub>6</sub>H<sub>5</sub>Cl</b>		<b>B = C<sub>7</sub>H<sub>8</sub> (5)</b>		<b>B = C<sub>7</sub>H<sub>8</sub> (5)</b>		20		-0.598		20		-5.488
0.1933		<b>B = C<sub>6</sub>H<sub>5</sub>Cl</b>		<b>B = C<sub>7</sub>H<sub>8</sub> (5)</b>		<b>B = C<sub>7</sub>H<sub>8</sub> (5)</b>		30		-0.816		30		-7.483
0.3060		<b>B = C<sub>6</sub>H<sub>5</sub>Cl</b>		<b>B = C<sub>7</sub>H<sub>8</sub> (5)</b>		<b>B = C<sub>7</sub>H<sub>8</sub> (5)</b>		40		-0.963		40		-8.706
0.3833		<b>B = C<sub>6</sub>H<sub>5</sub>Cl</b>		<b>B = C<sub>7</sub>H<sub>8</sub> (5)</b>		<b>B = C<sub>7</sub>H<sub>8</sub> (5)</b>		50		-1.030		50		-9.203
0.4947		<b>B = C<sub>6</sub>H<sub>5</sub>Cl</b>		<b>B = C<sub>7</sub>H<sub>8</sub> (5)</b>		<b>B = C<sub>7</sub>H<sub>8</sub> (5)</b>		60		-1.030		60		-9.010
0.5961		<b>B = C<sub>6</sub>H<sub>5</sub>Cl</b>		<b>B = C<sub>7</sub>H<sub>8</sub> (5)</b>		<b>B = C<sub>7</sub>H<sub>8</sub> (5)</b>		70		-0.912		70		-8.513
0.6802		<b>B = C<sub>6</sub>H<sub>5</sub>Cl</b>		<b>B = C<sub>7</sub>H<sub>8</sub> (5)</b>		<b>B = C<sub>7</sub>H<sub>8</sub> (5)</b>		80		-0.699		80		-6.910
0.7927		<b>B = C<sub>6</sub>H<sub>5</sub>Cl</b>		<b>B = C<sub>7</sub>H<sub>8</sub> (5)</b>		<b>B = C<sub>7</sub>H<sub>8</sub> (5)</b>		90		-0.452		$t = 3.2 \text{ to } 5.5^\circ$		
0.8579		<b>B = C<sub>6</sub>H<sub>5</sub>Cl</b>		<b>B = C<sub>7</sub>H<sub>8</sub> (5)</b>		<b>B = C<sub>7</sub>H<sub>8</sub> (5)</b>		<b>B = C<sub>7</sub>H<sub>8</sub> (118.2)</b>		10		-3.01		
0.9294		<b>B = C<sub>6</sub>H<sub>5</sub>Cl</b>		<b>B = C<sub>7</sub>H<sub>8</sub> (5)</b>		<b>B = C<sub>7</sub>H<sub>8</sub> (5)</b>		<b>Toluene</b>		20		-5.003		
<b>B = C<sub>6</sub>H<sub>12</sub>O<sub>2</sub> (94.1)</b>		<b>B = C<sub>6</sub>H<sub>5</sub>Cl</b>		<b>B = C<sub>7</sub>H<sub>8</sub> (5)</b>		<b>B = C<sub>7</sub>H<sub>8</sub> (5)</b>		$t = 17^\circ$		30		-7.551		
Paraldehyde		<b>B = C<sub>6</sub>H<sub>5</sub>Cl</b>		<b>B = C<sub>7</sub>H<sub>8</sub> (5)</b>		<b>B = C<sub>7</sub>H<sub>8</sub> (5)</b>		0.067		40		-8.844		
$t = 25^\circ$		<b>B = C<sub>6</sub>H<sub>5</sub>Cl</b>		<b>B = C<sub>7</sub>H<sub>8</sub> (5)</b>		<b>B = C<sub>7</sub>H<sub>8</sub> (5)</b>		0.138		50		-9.515		
0.2360		<b>B = C<sub>6</sub>H<sub>5</sub>Cl</b>		<b>B = C<sub>7</sub>H<sub>8</sub> (5)</b>		<b>B = C<sub>7</sub>H<sub>8</sub> (5)</b>		0.197		60		-9.607		
-0.210		<b>B = C<sub>6</sub>H<sub>5</sub>Cl</b>		<b>B = C<sub>7</sub>H<sub>8</sub> (5)</b>		<b>B = C<sub>7</sub>H<sub>8</sub> (5)</b>		0.264		70		-8.844		
-0.299		<b>B = C<sub>6</sub>H<sub>5</sub>Cl</b>		<b>B = C<sub>7</sub>H<sub>8</sub> (5)</b>		<b>B = C<sub>7</sub>H<sub>8</sub> (5)</b>		0.318		80		-7.369		
-0.314		<b>B = C<sub>6</sub>H<sub>5</sub>Cl</b>		<b>B = C<sub>7</sub>H<sub>8</sub> (5)</b>		<b>B = C<sub>7</sub>H<sub>8</sub> (5)</b>		0.335		$t = 15.5^\circ$		10		-3.229
-0.315		<b>B = C<sub>6</sub>H<sub>5</sub>Cl</b>		<b>B = C<sub>7</sub>H<sub>8</sub> (5)</b>		<b>B = C<sub>7</sub>H<sub>8</sub> (5)</b>		0.326		20		-5.896		
-0.300		<b>B = C<sub>6</sub>H<sub>5</sub>Cl</b>		<b>B = C<sub>7</sub>H<sub>8</sub> (5)</b>		<b>B = C<sub>7</sub>H<sub>8</sub> (5)</b>		0.276		30		-8.041		
-0.244		<b>B = C<sub>6</sub>H<sub>5</sub>Cl</b>		<b>B = C<sub>7</sub>H<sub>8</sub> (5)</b>		<b>B = C<sub>7</sub>H<sub>8</sub> (5)</b>		0.172		40		-9.296		
-0.132		<b>B = C<sub>6</sub>H<sub>5</sub>Cl</b>		<b>B = C<sub>7</sub>H<sub>8</sub> (5)</b>		<b>B = C<sub>7</sub>H<sub>8</sub> (5)</b>		<b>CS<sub>2</sub></b>		50		-10.47		
<b>B = C<sub>6</sub>H<sub>12</sub>O<sub>2</sub> (94.1)</b>		<b>B = C<sub>6</sub>H<sub>5</sub>Cl</b>		<b>B = C<sub>7</sub>H<sub>8</sub> (5)</b>		<b>B = C<sub>7</sub>H<sub>8</sub> (5)</b>		<b>B = CHCl<sub>3</sub> (118.2)</b>		60		-10.52		
Amyl formate		<b>B = C<sub>6</sub>H<sub>5</sub>Cl</b>		<b>B = C<sub>7</sub>H<sub>8</sub> (5)</b>		<b>B = C<sub>7</sub>H<sub>8</sub> (5)</b>		<b>Chloroform</b>		70		-9.524		
0.50		<b>B = C<sub>6</sub>H<sub>5</sub>Cl</b>		<b>B = C<sub>7</sub>H<sub>8</sub> (5)</b>		<b>B = C<sub>7</sub>H<sub>8</sub> (5)</b>		$t = 13^\circ$		80		-8.658		
0.036		<b>B = C<sub>6</sub>H<sub>5</sub>Cl</b>		<b>B = C<sub>7</sub>H<sub>8</sub> (5)</b>		<b>B = C<sub>7</sub>H<sub>8</sub> (5)</b>		10		-2.55				
<b>B = C<sub>6</sub>H<sub>14</sub>O<sub>2</sub> (101, 104)</b>		<b>B = C<sub>6</sub>H<sub>5</sub>Cl</b>		<b>B = C<sub>7</sub>H<sub>8</sub> (5)</b>		<b>B = C<sub>7</sub>H<sub>8</sub> (5)</b>		20		-4.44				
Amyl acetate		<b>B = C<sub>6</sub>H<sub>5</sub>Cl</b>		<b>B = C<sub>7</sub>H<sub>8</sub> (5)</b>		<b>B = C<sub>7</sub>H<sub>8</sub> (5)</b>		30		-5.65				
0.49		<b>B = C<sub>6</sub>H<sub>5</sub>Cl</b>		<b>B = C<sub>7</sub>H<sub>8</sub> (5)</b>		<b>B = C<sub>7</sub>H<sub>8</sub> (5)</b>		<b>CS<sub>2</sub></b>						
0.216		<b>B = C<sub>6</sub>H<sub>5</sub>Cl</b>		<b>B = C<sub>7</sub>H<sub>8</sub> (5)</b>		<b>B = C<sub>7</sub>H<sub>8</sub> (5)</b>		<b>B = CHCl<sub>3</sub> (118.2)</b>						
<b>B = C<sub>6</sub>H<sub>10</sub>O<sub>2</sub> (101, 104)</b>		<b>B = C<sub>6</sub>H<sub>5</sub>Cl</b>		<b>B = C<sub>7</sub>H<sub>8</sub> (5)</b>		<b>B = C<sub>7</sub>H<sub>8</sub> (5)</b>		<b>Chloroform</b>						
Ethyl benzoate		<b>B = C<sub>6</sub>H<sub>5</sub>Cl</b>		<b>B = C<sub>7</sub>H<sub>8</sub> (5)</b>		<b>B = C<sub>7</sub>H<sub>8</sub> (5)</b>		$t = 13^\circ$						
0.50		<b>B = C<sub>6</sub>H<sub>5</sub>Cl</b>		<b>B = C<sub>7</sub>H<sub>8</sub> (5)</b>		<b>B = C<sub>7</sub>H<sub>8</sub> (5)</b>		10		-2.55				
-0.227		<b>B = C<sub>6</sub>H<sub>5</sub>Cl</b>		<b>B = C<sub>7</sub>H<sub>8</sub> (5)</b>		<b>B = C<sub>7</sub>H<sub>8</sub> (5)</b>		20		-4.44				
<b>C<sub>4</sub>H<sub>10</sub>O</b>		<b>B = C<sub>6</sub>H<sub>5</sub>Cl</b>		<b>B = C<sub>7</sub>H<sub>8</sub> (5)</b>		<b>B = C<sub>7</sub>H<sub>8</sub> (5)</b>		30						



**CS<sub>2</sub>—(Continued)****B = C<sub>2</sub>H<sub>6</sub>O (118.2)**

Acetone

% A	Q
<i>t</i> = 16°	
10	-5.78
20	-11.80
30	-16.45
40	-19.92
50	-20.93
60	-20.80
70	-17.62
80	-16.15
90	-10.80

**B = C<sub>6</sub>H<sub>6</sub> (137)***t* = 0°

10	-2.117
20	-3.85
30	-5.235
40	-6.305
50	-6.690
70	-6.101
80	-4.860
90	-3.001

*t* = 4°

10	-2.109
20	-3.827
30	-5.220
40	-6.257
50	-6.600
70	-6.040
80	-4.847
90	-2.997

*t* = 14.5°

10	-2.090
20	-3.807
30	-5.127
40	-6.109
50	-6.468
70	-5.920
80	-4.782
90	-2.976

*t* = 18° (118.2)

10	-2.59
20	-4.85
30	-6.78
40	-7.70
50	-7.95
60	-7.83
70	-6.82
80	-5.15
90	-2.93

**B = C<sub>7</sub>H<sub>8</sub> (118.2)**

Toluene

*t* = 18°

10	-1.38
20	-2.64
30	-3.52
40	-4.44
50	-4.73
60	-4.60
70	-4.02
80	-3.01
90	-1.72

**CHCl<sub>3</sub>**

Chloroform

**B = C<sub>2</sub>H<sub>6</sub>O (118.2)**

Acetone

% A | Q

*t* = 14°

10	4.77
20	9.83
30	14.31
40	19.38
50	23.27
60	25.53
70	25.07
80	21.55
90	13.56

**B = C<sub>4</sub>H<sub>10</sub>O (118.2)**

Ethyl ether

*t* = 14°

10	7.49
20	13.89
30	18.71
40	23.48
50	26.53
60	25.99
70	23.77
80	18.83
90	10.21

**B = C<sub>6</sub>H<sub>6</sub> (118.2)***t* = 18°

10	1.13
20	2.01
30	2.64
40	3.10
50	3.31
60	3.31
70	3.18
80	2.89
90	2.05

**CH<sub>3</sub>O**

Methyl alcohol

**B = C<sub>2</sub>H<sub>6</sub>O**

Ethyl alcohol

*t* = 0.3° (48)

32.17	-0.322
67.83	-0.272
85.87	-0.146
<i>t</i> = 16° (118.2)	
10	0.209
20	0.343
30	0.393
40	0.398
50	0.360
60	0.314
70	0.268
80	0.184
90	0.100

*t* = 20.8° (48)

32.3	-0.029
49.6	-0.029

**B = C<sub>2</sub>H<sub>6</sub>O***n*-Propyl alcohol*t* = 0.3° (48)

32.84	-2.059
47.44	-2.239
70.84	-1.892

**B = C<sub>2</sub>H<sub>6</sub>O—**

(Continued)

% A | Q

*t* = 14° (118.2)

10	-0.75
20	-1.46
30	-2.05
40	-2.34
50	-2.30
60	-2.05
70	-1.72
80	-1.26
90	-0.71

*t* = 21.3° (48)

25.56	-1.507
50.03	-2.101
67.46	-1.908
82.41	-1.427

**B = C<sub>6</sub>H<sub>6</sub> (118.2)***t* = 15°

10	-9.33
20	-9.54
30	-10.17
40	-9.50
50	-8.29
60	-6.65
70	-4.98
80	-3.35
90	-1.72

**C<sub>2</sub>H<sub>4</sub>O<sub>2</sub>**

Acetic acid

**B = C<sub>6</sub>H<sub>6</sub> (118.2)***t* = 16°

10	-2.39
20	-3.68
30	-4.81
40	-5.52
50	-5.98
60	-5.69
70	-5.06
80	-3.93
90	-2.39

**C<sub>2</sub>H<sub>6</sub>O**

Ethyl alcohol

**B = C<sub>2</sub>H<sub>6</sub>O (48)***n*-Propyl alcohol*t* = 0.27°

45.2	-0.469
62.17	-0.594
<i>t</i> = 21°	
32.86	-0.586
49.58	-0.523

**B = C<sub>6</sub>H<sub>6</sub> (137)***t* = 0°

10	-4.045
20	-5.253
30	-6.055
40	-6.410
60	-6.120
70	-5.697
80	-4.414
90	-2.550
<i>t</i> = 3.1 to 5.9°	
10	-4.320
20	-5.769

**B = C<sub>2</sub>H<sub>6</sub>—**

(Continued)

% A | Q

*t* = 15°

30	-6.550
40	-6.767
60	-6.411
70	-5.812
80	-4.469
90	-2.572

*t* = 15°

10	-5.416
20	-6.706
30	-7.338
40	-7.556
60	-6.867
70	-6.067
80	-4.578
90	-2.658

**C<sub>3</sub>H<sub>6</sub>O**

Acetone

**B = C<sub>6</sub>H<sub>6</sub>ClO (50)***o*-Chlorophenol*t* = 0°

13.90	32.58
17.10	38.00
19.10	40.52
21.90	44.28
23.70	45.70
26.00	47.08
27.55	47.79
29.35	48.55
31.15	48.67
33.80	48.42
37.60	47.63
42.70	45.57
44.05	45.11
50.00	41.93
53.45	39.24
62.00	33.30

**C<sub>3</sub>H<sub>8</sub>O<sub>2</sub>**

Methyl acetate

**B = C<sub>2</sub>H<sub>6</sub>O<sub>2</sub> (118.2)**

Ethyl acetate

*t* = 16°

10	-0.326
20	-0.594
30	-0.757
40	-0.850
50	-0.866
60	-0.787
70	-0.678
80	-0.511
90	-0.293

**B = C<sub>6</sub>H<sub>6</sub> (118.2)***t* = 17°

10	-2.39
20	-4.52
30	-5.86
40	-6.36
50	-6.32
60	-5.69
70	-4.81
80	-3.64
90	-2.13

**C<sub>3</sub>H<sub>8</sub>O***n*-Propyl alcohol**B = C<sub>6</sub>H<sub>6</sub> (118.2)***t* = 15°

% A   Q	
10	-10.30
20	-12.64
30	-13.56
40	-13.22
50	-12.26
60	-11.09
70	-8.29
80	-5.52
90	-2.76

**C<sub>4</sub>H<sub>8</sub>O<sub>2</sub>**

Ethyl acetate

**B = C<sub>6</sub>H<sub>10</sub>O (118.2)**

Ethyl ether

*t* = 14°

10	-1.09
20	-1.76
30	-2.34
40	-2.76
50	-2.97
60	-2.76
70	-2.43
80	-1.88
90	-1.13

**B = C<sub>6</sub>H<sub>6</sub> (118.2)***t* = 17°

10	-0.879
20	-1.310
30	-1.465
40	-1.528
50	-1.515
60	-1.444
70	-1.327
80	-1.109
90	-0.682

**B = C<sub>7</sub>H<sub>14</sub>O<sub>2</sub>**

Amyl acetate (118.2)

*t* = 15°

10	-0.67
20	-1.00
30	-1.55
40	-1.84
50	-1.88
60	-1.76
70	-1.46
80	-1.13
90	-0.67

**C<sub>4</sub>H<sub>10</sub>O**

Ethyl ether

**B = C<sub>6</sub>H<sub>6</sub> (118.2)***t* = 15°

10-90 | 0.00

**C<sub>5</sub>H<sub>5</sub>N**

Pyridine

**B = C<sub>6</sub>H<sub>6</sub>ClO (50)***o*-Chlorophenol*t* = 0°

15.0	63.19
22.0	73.61

**B = C<sub>6</sub>H<sub>6</sub>ClO—**

(Continued)

% A | Q

25.1	78.01
30.0	85.08
34.0	89.18
38.1	91.15
41.1	90.19
46.9	84.70
55.1	72.74
61.0	63.44

**B = C<sub>7</sub>H<sub>8</sub>O (50)***o*-Cresol*t* = 0°

17.5	52.94
25.05	68.63
30.7	76.25
36.4	80.64
39.9	81.11
40.2	81.31
44.85	79.39
48.7	75.79
49.9	74.79
50.85	73.53
57.25	64.74
57.65	64.66
63.0	53.15

**B = C<sub>7</sub>H<sub>8</sub>O (50)***m*-Cresol*t* = 0°

9.85	26.03
19.5	45.87
27.5	57.54
33.1	61.60
36.8	63.70
42.2	63.24
49.05	58.97
54.25	54.66
61.00	47.54
68.25	38.54
82.9	21.42

**C<sub>5</sub>H<sub>12</sub>O**

Amyl alcohol

**B = C<sub>6</sub>H<sub>10</sub> (55)***p*-Xylene*t* = 0°

20.6	4.48
39.2	6.57
46.5	6.78
53.1	6.40
64.8	5.23
72.7	3.81

**C<sub>6</sub>H<sub>5</sub>ClO***o*-Chlorophenol**B = C<sub>6</sub>H<sub>11</sub>N (50)**

Dimethylaniline

*t* = 0°

40.5	20.51
45.7	22.23
49.0	23.30
51.2	23.87
54.2	24.81
57.4	25.80
60.5	26.40
62.6	26.38



[illegible]

TABLE 5

The concentration is expressed by the number of moles of solvent,  $M_s$ , added to one mole of solute. The B-component where italicized is the solute, and is otherwise the solvent.  $Q$  is expressed in kilojoules evolved per mole solute.

$H_2O$ $B = CH_2O_2$ (64) Formic acid		$B = C_2H_2Cl_2O_2$ Dichloroacetic acid		$B = C_3H_5O_2$ (64) Propionic acid		$H_2O$ $B = CH_4O$ (49) Methyl alcohol		$B = CH_4O$ — (Continued)		$B = C_2H_5O$ (49) Ethyl alcohol	
$M_a$	$Q$	$M_a$	$Q$	$M_a$	$Q$	$M$	$\% A$	$M$	$\% A$	$M$	$\% A$
0.135	0.348	$t = 15.9^\circ$ (115)		$t = 8^\circ$		$t = 0^\circ$		$t = 42.37^\circ$		$t = 0^\circ$	
0.28	0.744	196	9.63	0.216	-1.40	5	0.159	50	1.632	5	0.088
0.45	1.061	398	10.80	0.456	-2.00	10	0.310	55	1.896	10	0.176
0.85	1.430	776	11.59	0.720	-2.29	15	0.460	60	2.218	15	0.289
1.10	1.460			1.027	-2.46	20	0.607	65	2.591	20	0.410
1.70	1.445			1.718	-2.62	25	0.762	70	3.055	25	0.498
5.96	1.299			2.740	-2.52	30	0.925	75	3.666	30	0.590
48.55	1.257			4.110	-2.35	35	1.105	80	4.357	35	0.691
				9.590	-1.79	40	1.297	85	5.114	40	0.824
				14.570	-1.48	45	1.511	90	5.989	45	1.004
				38.270	-1.26	50	1.766	95	6.838	50	1.251
				78.110	-1.25	55	2.038			55	1.523
						60	2.381	$t = 17.33^\circ$		60	1.900
						65	2.783	5	0.071	65	2.385
						70	3.306	10	0.151	70	3.038
						75	3.967	15	0.251	75	3.972
						80	4.763	20	0.356	80	5.428
						85	5.750	25	0.473	85	7.407
						90	6.905	30	0.594	90	9.856
						95	8.328	35	0.724	95	12.54
						$t = 19.69^\circ$		40	0.866		
						5	0.134	45	1.013	5	0.042
						10	0.272	50	1.193	10	0.092
						15	0.419	55	1.402	15	0.167
						20	0.569	60	1.632	20	0.251
						25	0.716	65	1.908	25	0.335
						30	0.862	70	2.264	30	0.423
						35	1.017	75	2.691	35	0.519
						40	1.197	80	3.185	40	0.636
						45	1.398	85	3.725	45	0.757
								90	4.352	50	0.946
								95	4.997		

$B = C_2H_3BrO_2$ Bromoacetic acid (solid)		$B = C_4H_8O_2$ (64) n-Butyric acid		$B = C_2H_4O_2$ Acetic acid (64)		$C_2H_4Br_2$ Ethylene bromide	
$t$	$Q$	$t$	$Q$	$t$	$Q$	$B$	$Q$
$t = 15.2^\circ$ (115)		$t = 9^\circ$				$B = C_2H_4O_2$ (4)	
206	1.05	0.25	-1.00	0.25	-0.293	Acetic acid	
417	1.99	0.54	-1.49	0.58	-0.527	0.30	0.55
799	2.62	0.86	-1.77	1.11	-0.624	0.528	0.845
$\infty$	3.52	1.22	-1.93	1.42	-0.624	1.06	1.318
		1.63	-2.04	1.95	-0.544		
		2.09	-2.08	5.00	-0.310		
		3.05	-2.08	6.19	+0.056		
		3.67	-1.99	30.00	0.386		
		7.33	-1.68	63.33	0.449		
		19.55	-1.24				
		44.00	-0.91				
		93.00	-0.73				

$B = C_2H_3Br_2O_2$ Dibromoacetic acid (solid)		$B = C_2H_4O_2$ Acetic acid	
$t$	$Q$	$t$	$Q$
$t = 15.3^\circ$ (115)		$t = 18.5^\circ$ (115)	
364	-1.18	139	1.12
479	-3.76	197	1.53*
712	-3.42	207	1.15
		411	1.37
		$\infty$	1.90
		* 13.6°.	

TABLE 6

The concentration is expressed as the mole per cent of the A-component in the mixture.  $Q$  is expressed in kilojoules evolved per mole B.



**H<sub>2</sub>O.—(Cont'd)****B = C<sub>2</sub>H<sub>5</sub>O.—**  
(Continued)

M % A	Q
55	1.201
60	1.507
65	1.925
70	2.478
75	3.218
80	4.269
85	5.821
90	7.801
95	9.818

*t* = 42.05°

5	0.0029
10	0.0063
15	0.013
20	0.023
25	0.042
30	0.075
35	0.109
40	0.167
45	0.243
50	0.343
55	0.465
60	0.649
65	0.870
70	1.209
75	1.691
80	2.356
85	3.281
90	4.528
95	6.236

**B = C<sub>3</sub>H<sub>7</sub>O (49)****n-Propyl alcohol****M % A | Q***t* = 0°

5	-0.011
10	-0.021
15	-0.027
20	-0.019
25	-0.008
30	+0.010
35	0.042
40	0.092
45	0.167
50	0.264
55	0.419
60	0.590
65	0.883
70	1.264
75	1.354
80	2.758
85	4.323
90	7.382
95	12.68

*t* = 21.03°

5	-0.042
10	-0.084
15	-0.121
20	-0.159
25	-0.197
30	-0.230
35	-0.243
40	-0.243
45	-0.209
50	-0.167

**B = C<sub>3</sub>H<sub>7</sub>O.—****(Continued)****M % A | Q**

55	-0.084
60	+0.038
65	0.201
70	0.431
75	0.778
80	1.335
85	2.264
90	4.110
95	7.981

*t* = 43.44°

5	-0.105
10	-0.205
15	-0.306
20	-0.402
25	-0.498
30	-0.590
35	-0.670
40	-0.737
45	-0.778
50	-0.795
55	-0.795
60	-0.770
65	-0.728
70	-0.644
75	-0.502
80	-0.259
85	+0.176
90	0.586
95	3.055

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- (30) Berthelot, 6, 21: 372; 90. (31) Berthelot, 6, 21: 416; 90. (32) Berthelot, 6, 23: 563; 91. (33) Berthelot, 6, 4: 117; 95. (34) Berthelot, 6, 7: 50; 96. (35) Berthelot and Fogh, 6, 22: 18; 91. (36) Berthelot and Jungfleisch, 6, 4: 147; 75. (37) Berthelot and Louguinine, 6, 6: 289; 75. (38) Berthelot and Matignon, 6, 21: 409; 90. (39) Berthelot and Matignon, 6, 20: 565; 93. (40) Berthelot and Ogier, 6, 23: 199; 81. (41) Berthelot and Ogier, 6, 23: 200; 81. (42) Berthelot and Petit, 6, 20: 5; 90. (43) Berthelot and Petit, 6, 20: 13; 90. (44) Berthelot and Werner, 6, 7: 103; 86. (45) Berthelot and Werner, 6, 7: 117; 86. (46) Berthelot and Werner, 6, 7: 145; 86. (47) Bonnefoi, 34, 127: 516; 98. (48) Bose, 188, 1906: 309. (49) Bose, 7, 58: 585; 07. (50) Bramley, 4, 109: 496; 16. (51) Carroll and Mathews, 1, 46: 30; 24. (52) Cavalier, 34, 122: 1486; 96. (53) Chancel and Parmentier, 34, 104: 474; 87. (54) Chroustchhoff, 6, 19: 422; 80. (55) Clark, 63, 6: 154; 05. (56) Cohen and Moesveld, 7, 93: 385; 19. (57) Colson, 6, 8: 282; 86. (58) Colson, 6, 19: 407; 90. (59) Colson, 34, 111: 266; 90. (60) Colson and Darzens, 34, 118: 250; 94. (61) Combes, 27, 49: 910; 88. (62) Delépine, 34, 123: 888; 96. (63) Drucker and Moles, 7, 75: 405; 11. (64) Faucon, 6, 19: 70; 10. (65) Favre, 34, 51: 316; 60. (66) de Forcrand, 6, 3: 187; 84. (67) de Forcrand, 34, 101: 1495; 85. (68) de Forcrand, 34, 102: 551; 86. (69) de Forcrand, 34, 102: 1398; 86. (70) de Forcrand, 6, 11: 445; 87. (71) de Forcrand, 6, 11: 483; 87. (72) de Forcrand, 34, 107: 270; 88. (73) de Forcrand, 6, 20: 433; 90. (74) de Forcrand, 6, 26: 201; 92. (75) de Forcrand, 6, 27: 525; 92. (76) de Forcrand, 34, 114: 420; 92. (77) de Forcrand, 34, 114: 1062; 92. (78) de Forcrand, 6, 30: 56; 93. (79) de Forcrand, 34, 118: 922; 94. (80) de Forcrand, 34, 118: 1101; 94. (81) de Forcrand, 34, 120: 737; 95. (82) de Forcrand, 34, 154: 1768; 12. (83) Gal and Werner, 34, 103: 1019; 86. (84) Gal and Werner, 27, 46: 801; 86. (85) Gal and Werner, 27, 46: 803; 86. (86) Gal and Werner, 27, 47: 158; 87. (87) Gautier, Thesis, Paris, 1888. (88) Gehlhoff, 7, 98: 252; 21. (89) Gerlach, 91, 24: 106; 84. (90) Goldschmidt and Maarseveen, 7, 25: 91; 98. (91) Guntz, 6, 13: 388; 88. (92) Haller and Guntz, 34, 106: 1473; 88. (93) Hartung, 83, 12: 66; 17. (94.1) Hirobe, 44, 1: 155; 26. (95) Joannis, 6, 26: 530; 82. (96) Jorissen and van de Stadt, 52, 51: 102; 94. (97) Katayama and Tomiyama, 41, 36: 745; 15. (98) Katz, 64P, 13: 958; 11. (99) Keyes and Hildebrand, 1, 39: 2126; 17. (100) de Kolosovsky, 28, 1913: 340. (101) Kremann, 57, 37: 11; 16. (102) Kremann and Borjanovics, 57, 37: 59; 16. (103) Kremann, Kerschbaum and Pilch, 57, 31: 203; 10. (104) Kremann, Meingast and Gugl, 57, 35: 1235; 14. (104.1) de Leew, 7, 77: 284; 11. (105) Lemoult, 34, 123: 559; 96. (106) Louguinine, 6, 17: 229; 79. (107) Massol, 34, 113: 800; 91. (108) Massol, 6, 1: 145; 94. (109) Mathews, 1, 33: 1291; 11. (110) Matignon, 6, 28: 70; 93. (111) Matignon, 6, 28: 77; 93. (112) Matignon, 6, 28: 289; 93. (112.5) Parks and Chaffee, 50, 31: 427; 27. (113) Parks and Schwenck, 50, 28: 720; 24. (114) Petit, 6, 18: 145; 89. (115) Pickering, 4, 67: 664; 95. (116) Rivals, 34, 122: 480; 96. (117) Sameshima, 1, 40: 1482; 18. (118) Sameshima, 1, 40: 1503; 18. (118.1) Sandonnini, 22, 1: 448; 25. (118.2) Schmidt, 7, 121: 221; 26. (119) Schwes, 28, 1908: 833. (120) Shukarev, 7, 71: 90; 10. (121) Sidgwick and Turner, 4, 121: 2256; 22. (122) Speyers, 1, 18: 146; 96. (123) Swietoslawski, 25, 43: 1479; 10. (124) Tanatar, 53, 23: 243; 91. 4, 64 II: 108; 93. (125) Tanatar, 53, 24: 365; 92. 4, 64 II: 358; 93. (126) Timofeev, 34, 112: 1137; 91. (127) Timofeev, 185, 76 II: 429; 05. (128) Tsakalotos and Guye, 42, 8: 340; 10. (129) Tscheltzow, 6, 8: 233; 86. (130) Tyrer, 4, 101: 81; 12. (131) Viala, 27, 15: 5; 14. (132) Vignon, 34, 106: 1671; 88. (133) Vignon, 34, 109: 477; 89. (134) Vignon, 34, 115: 354; 92. (135) Werner, 6, 3: 567; 84. (136) Wiedemann and Lüdeking, 8, 25: 145; 85. (137) Winkelmann, 8, 30: 592; 73. (138) Winkelmann, 7, 60: 626; 07.

**HEAT OF DILUTION****FRANK R. PRATT****INTRODUCTION**

If to a solution having an initial concentration  $C_1$  and at the temperature  $t$ , °C water at  $t^\circ$  is added in sufficient amount to change the concentration to  $C_2$ , it is necessary to abstract from the system  $H$  joules of heat in order to keep its temperature constant, the amount of solution being that shown by the quantities in which  $C_1$  is expressed. For example, in the table for KCl below; if to a solution composed of 1 gram-mole of KCl and 25 gram-moles of H<sub>2</sub>O,  $C_1$  (=400) at 18°C, 25 gram-moles of H<sub>2</sub>O at 18°C be added, the final concentration will be  $C_2$  (=200) and 794 joules of heat must be supplied (because of the negative sign) to the resulting mixture in order to maintain it at 18°C. It is the quantity  $H$  which (unless otherwise indicated) is recorded below. The values

given have been interpolated from the original drawings of the graphs of Pratt, 143, 185: 663; 18.

**TABLE****Ethyl alcohol (Squibb's),  $C_1 \approx 400 = 1M$  C<sub>2</sub>H<sub>5</sub>OH and 25M H<sub>2</sub>O**

<i>t</i> , °C	$C_2$							
	300	240	200	160	100	80	60	40
0	309	447	531	602	702	744	782	
5	301	443	523	594	694	732	765	
10	293	435	514	585	686	719	753	
15	288	422	506	577	677	711	736	
20	280	414	493	569	665	694	719	
25	272	406	485	560	656	681	702	
30	263	397	477	552	648	677	690	
33.5	255	389	468	544	635	656	673	

s. further  
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Resorcinol,  $C_1 \approx 400 = 1M C_6H_6O_2$  and 25M  $H_2O$ 

$t, ^\circ C$	$C_1$								
	300	240	200	160	100	80	60	40	20
0	-21	-50	-84	-125	-217	-251	-293	-343	-376
5	-38	-79	-113	-167	-272	-301	-360	-418	-468
10	-54	-100	-142	-201	-309	-360	-418	-485	-560
15	-67	-125	-171	-234	-364	-418	-481	-560	-635
20	-84	-151	-205	-272	-410	-460	-544	-627	-744
25	-100	-176	-230	-314	-460	-527	-615	-744	-828
30	-117	-201	-268	-343	-502	-585	-669	-773	-920
33.5	-134	-226	-293	-376	-544	-619	-719	-836	-1003

Pyrocatechol,  $C_1 \approx 400 = 1M C_6H_6O_2$  and 25M  $H_2O$ 

0	326	544	711	899	1187	1275	1359	1432	
5	293	489	635	811	1070	1162	1233	1296	
10	259	439	573	727	970	1045	1108	1171	
15	226	376	502	635	840	920	983	1045	
20	188	326	426	543	732	794	857	920	
25	151	272	351	452	619	673	736	794	
30	121	217	280	363.7	506	552	606	669	
33.5	100	167	226	301.0	418	460	502	552	

 $\frac{1}{2}$  Hydroquinol,  $C_1 \approx 400 = 1M C_6H_6O_2$  and 400M  $H_2O$ 

0	10.0	13.8	14.2	12.5	-3.3	-13.4			
5	6.3	8.4	8.4	6.3	-7.9	-15.1			
10	3.8	4.2	3.3	0.4	-11.7	-18.0			
15	1.3	0	-1.7	-5.4	-15.1	-19.2			
20	-2.1	-5.0	-7.5	-11.3	-20.1	-23.0			
25	-5.9	-10.0	-13.0	-16.7	-23.0	-25.5			
30	-8.8	-14.2	-17.1	-20.5	-25.5	-27.2			
33.5	-12.1	-18.4	-21.7	-24.2	-26.7	-27.2			

 $\frac{1}{2}$  Mannitol,  $C_1 \approx 400 = 1M C_6H_{14}O_6$  and 50M  $H_2O$ 

0	4.2	3.8	2.1	-3.3	-14.6				
5	6.7	8.4	6.7	5.0	-0.8				
10	7.1	10.5	11.3	11.3	11.3				
15	7.5	12.5	15.1	19.2	25.1				
20	9.2	16.3	21.7	28.4	39.7				
25	9.2	16.7	23.8	33.0	50.2				
30	13.0	21.7	30.1	41.8	64.8				
33.5	13.4	23.8	33.4	46.8	76.9				

Dextrose,  $C_1 \approx 400 = 1M C_6H_{12}O_6 \cdot H_2O$  and 25M  $H_2O$ 

0	167	268	343						
5	167	268	343						
10	167	268	343						
15	167	268	343						
20	167	268	343	431	560	606	652	690	
25	167	268	343	427	544	585	623	656	
30	167	268	343	418	527	560	594	623	
33.5	167	268	343	414	510	543	564	594	

Sucrose,  $C_1 \approx 400 = 1M C_{12}H_{22}O_{11}$  and 25M  $H_2O$ 

0	247	393	481	564	673	707	736	769	
5	247	393	485	573	694	732	773	815	
10	247	397	493	585	719	761	807	857	
15	247	397	497	594	744	794	849	916	
20	247	401	502	606	769	824	891	962	
25	247	401	510	619	790	853	924	1008	
30	247	406	518	631	819	886	962	1054	
33.5	247	410	522	644	836	907	991	1095	

1.847 NaOH,  $C_1 \approx 800 = 2M NaOH$  and 25M  $H_2O$ 

$t, ^\circ C$	$C_1$							
	720	300	200	140	80	60	40	20
0	-63	-1534	-2279	-2885	-3617	-3847		
5	-42	-1200	-1831	-2300	-2835	-2989	-3169	-3345
10	-21	-911	-1401	-1756	-2132	-2237	-2354	-2467
15	4	-619	-1016	-1254	-1480	-1559	-1647	-1714
20	8	-334	-606	-778	-928	-978	-1020	-1066
25	12	-63	-242	-355	-447	-477	-489	-493
30	17	171	84	21	-42	-50	-63	-67
33.5	21	343	326	284	251	247	247	247

1.645 KOH,  $C_1 \approx 800 = 2M KOH$  and 25M  $H_2O$ 

$t, ^\circ C$	$C_1$						
	640	300	200	140	80	60	40
0	0	-355	-719	-1003	-1317	-1422	-1547
5	13	-96	-385	-544	-753	-828	-899
10	25	138	4	-100	-209	-251	-293
15	38	355	326	284	251	251	263
20	50	560	606	652	690	719	773
25	63	744	870	953	1066	1129	1204
30	71	903	1087	1213	1392	1484	1589
33.5	79	983	1204	1346	1555	1651	1756

1.17  $NH_4Cl$ ,  $C_1 \approx 400 = 1.17M NH_4Cl$  and 25M  $H_2O$ 

$t, ^\circ C$	$C_1$								
	300	240	200	160	100	80	60	40	20
0	-255	-431	-556	-698	-920	-983	-1037	-1087	
2	-238	-397	-514	-640	-836	-899	-937	-978	
4	-230	-364	-472	-585	-757	-811	-840	-861	
6	-201	-334	-431	-535	-669	-711	-744	-753	
8	-184	-305	-389	-468	-594	-619	-644	-644	
10	-167	-276	-351	-418	-518	-544	-552	-552	
12	-151	-247	-309	-368	-452	-468	-460	-477	-334
14	-138	-230	-272	-318	-385	-393	-385	-339	-226
16	-125	-201	-238	-272	-314	-314	-309	-255	-142
18	-109	-167	-201	-226	-247	-238	-222	-167	-42
20	-92	-134	-163	-176	-176	-167	-151	-84	+84

 $NH_4Cl$ ,  $C_1 \approx 400 = 1M NH_4Cl$  and 25M  $H_2O$ 

22	-63	-88	-96	-96	-96	-96	-84	-21
24	-46	-59	-67	-67	-42	-25	8	159
26	-33	-42	-33	-29	4	33	84	155
28	-17	-13	0	13	59	84	142	234
30	-4	8	25	42	100	125	192	272
32	8	33	50	71	134	167	209	293
33.5	21	46	67	92	155	192	230	305

KCl,  $C_1 \approx 400 = 1M KCl$  and 25M  $H_2O$ 

0	-594	-974	-1246	-1547	-2095	-2308	-2530	-2718	-2843
2	-564	-924	-1179	-1484	-2007	-2195	-2404	-2575	-2663
4	-543	-907	-1129	-1409	-1902	-2091	-2279	-2438	-2509
6	-518	-845	-1087	-1346	-1819	-1999	-2174	-2329	-2366
8	-481	-807	-1037	-1288	-1735	-1902	-2070	-2195	-2245
10	-460	-761	-983	-1217	-1631	-1781	-1944	-2086	-2111
12	-439	-727	-937	-1162	-1547	-1697	-1835	-1957	-1982
14	-418	-702	-891	-1100	-1463	-1589	-1735	-1840	-1848
16	-397	-661	-845	-1037	-1388	-1505	-1639	-1748	-1748
18	-376	-619	-794	-983	-1325	-1421	-1547	-1631	-1631
20	-355	-585	-753	-928	-1233	-1338	-1455	-1534	-1505
22	-326	-552	-707	-878	-1162	-1258	-1363	-1432	-1421
24	-313	-518	-665	-828	-1091	-1179	-1267	-1325	-1296
26	-293	-489	-627	-773	-1020	-1104	-1183	-1237	-1191
28	-280	-460	-585	-723	-953	-1033	-1104	-1145	-1087
30	-272	-439	-556	-681	-891	-962	-1003	-1041	-974
32	-251	-410	-523	-635	-815	-907	-932	-962	-853
33.5	-238	-389	-493	-594	-773	-828	-874	-899	-786

 $\frac{1}{2} SrCl_2$ ,  $C_1 \approx 400 = 1M SrCl_2$  and 50M  $H_2O$ 

14	-33	-54	-59	-46	-25	8	54	159	401
16	-17	-33	-13	13	54	88	146	251	493
18	0	33	33	63	134	171	230	334	585
20	21	50	84	121	209	251	309	427	669
22	42	92	134	184	276	330	389	506	753
24	59	117	163	217	334	389	460	585	828
26	75	142	197	268	414	460	535	669	911
28	92	171	230	314	456	514	594	744	978
30	117	201	272	351	506	577	661	799	1024
32	134	226	301	397	560	631	727	857	1095
33.5	146	251	330	426	602	677	773	920	1158

 $\frac{1}{2} SrCl_2$ ,  $C_1 \approx 400 = 1M SrCl_2 \cdot 6H_2O$  and 50M  $H_2O$ 

0	-70	-117	-146	-184	-234				
2	-59	-100	-125	-151	-171				
4	-52	-84	-105	-113	-125				
6	-46	-71	-75	-84	-88				
8	-40	-59	-54	-54	-54				
10	-33	-42	-38	-38	-29				
12	-25	-25	-25	-17	+4				

 $\frac{1}{2} BaCl_2$ ,  $C_1 \approx 400 = 1M BaCl_2$  and 25M  $H_2O$ 

14	- 125	- 192	- 226	- 251	- 272	- 276	- 251	- 180	42
16	- 105	- 151	- 167	- 188	- 192	- 188	- 146	- 63	167
18	- 84	- 117	- 125	- 117	- 105	- 8	- 42	50	251
20	- 63	- 75	- 75	- 63	- 17	4	59	163	376
22	- 42	- 42	- 38	0	63	92	159	255	447
24	- 21	4	38	59	134	167	247	343	573
26	0	33	63	109	201	251	314	426	635
28	21	63	109	167	280	326	401	510	732
30	42	105	151	226	347	397	489	552	794
32	63	134	201	272	418	468	564	594	857
33.5	84	163	226	309	460	523	615	619	920



$\frac{1}{2}\text{BaCl}_2$ ,  $C_1 \approx 400 = 1\text{M BaCl}_2 \cdot 2\text{H}_2\text{O}$  and  $50\text{M H}_2\text{O}$ .—(Cont'd)

$t, ^\circ\text{C}$	$C_1$								
	300	240	200	160	100	80	60	40	20
8	-146	-230	-280	-330	-385	-393	-393	-376	
10	-125	-197	-230	-268	-293	-293	-276	-234	
12	-109	-163	-188	-205	-201	-192	-159	-84	

 $\text{NH}_4\text{NO}_3$ ,  $C_1 \approx 400 = 1\text{M NH}_4\text{NO}_3$  and  $25\text{M H}_2\text{O}$ 

0	-1108	-1819	-2299	-2843	-3721	-4014	-4327	-4641	-5017
5	-1024	-1693	-2132	-2634	-3420	-3679	-3972	-4223	-4515
10	-983	-1589	-1986	-2425	-3094	-3345	-3596	-3847	-4139
15	-899	-1442	-1827	-2216	-2843	-3040	-3261	-3491	-3763
20	-836	-1338	-1672	-2019	-2571	-2759	-2969	-3157	-3387
25	-773	-1233	-1568	-1852	-2362	-2530	-2697	-2885	-3010
30	-727	-1150	-1442	-1723	-2153	-2320	-2446	-2592	-2697
33.5	-669	-1066	-1355	-1622	-2028	-2174	-2362	-2425	-2488

 $\text{NaNO}_3$ ,  $C_1 \approx 400 = 1\text{M NaNO}_3$  and  $25\text{M H}_2\text{O}$ 

0	-1233	-2007	-2659	-3261	-4348	-4725	-5184	-5561	-5895
5	-1087	-1798	-2333	-2885	-3847	-4223	-4599	-4975	-5226
10	-1003	-1647	-2132	-2634	-3512	-3847	-4181	-4515	-4766
15	-911	-1497	-1915	-2375	-3178	-3470	-3763	-4056	-4265
20	-836	-1380	-1756	-2174	-2885	-3178	-3408	-3658	-3805
25	-769	-1254	-1631	-2007	-2592	-2822	-3044	-3219	-3387
30	-690	-1154	-1497	-1840	-2341	-2542	-2709	-2885	-3010
33.5	-661	-1087	-1396	-1714	-2174	-2341	-2475	-2592	-2676

 $\text{KNO}_3$ ,  $C_1 \approx 400 = 1\text{M KNO}_3$  and  $25\text{M H}_2\text{O}$ 

0	-1547	-2634	-3408	-4348	-6062	-6815	-7526	-8362	-9073
5	-1505	-2509	-3219	-4014	-5561	-6104	-6690	-7359	-8069
10	-1421	-2341	-2969	-3721	-5059	-5519	-6021	-6564	-7108
15	-1338	-2174	-2843	-3512	-4683	-5101	-5519	-5979	-6439
20	-1212	-2007	-2592	-3219	-4348	-4683	-5101	-5519	-5853
25	-1150	-1923	-2425	-3094	-4014	-4390	-4725	-5101	-5477
30	-1095	-1840	-2383	-2885	-3805	-4139	-4474	-4808	-5101
33.5	-1045	-1756	-2258	-2759	-3721	-3930	-4181	-4515	-4808

 $\frac{1}{2}\text{Ba}(\text{NO}_3)_2$ ,  $C_1 \approx 400 = 1\text{M Ba}(\text{NO}_3)_2$  and  $25\text{M H}_2\text{O}$ 

0	-197	-334	-443	-564	-761	-836	-911	-1003	-1087
5	-171	-293	-376	-468	-640	-702	-761	-836	-1003
10	-151	-255	-334	-418	-556	-606	-665	-711	-732
15	-138	-226	-293	-364	-472	-514	-552		
20	-125	-201	-255	-314	-401	-431	-460		
25	-113	-176	-222	-268	-351	-376	-389		
30	-96	-159	-192	-251	-318	-330	-334		
33.5	-84	-146	-176	-234	-284				

 $\frac{1}{2}\text{Sr}(\text{NO}_3)_2$ ,  $C_1 \approx 400 = 1\text{M Sr}(\text{NO}_3)_2$  and  $50\text{M H}_2\text{O}$ 

$t, ^\circ\text{C}$	$C_1$								
	300	240	200	160	100	80	60	40	20
0	-978	-1568	-2049	-2571	-3512	-3847	-4181	-4641	-5184
5	-911	-1497	-1902	-2363	-3177	-3428	-3742	-4076	-4453
10	-832	-1359	-1735	-2132	-2835	-3073	-3324	-3617	-3888
15	-753	-1212	-1568	-1923	-2530	-2718	-2948	-3157	-3387
20	-686	-1108	-1401	-1714	-2216	-2404	-2592	-2739	-2843
25	-602	-974	-1233	-1526	-1965	-2091	-2216	-2341	
30	-518	-845	-1087	-1321	-1706	-1819	-1902	-2007	
33.5	-435	-732	-983	-1171	-1526	-1589	-1672	-1735	

## HEAT OF DILUTION OF AQUEOUS SOLUTIONS OF ETHYL AND METHYL ALCOHOLS

If  $m$  grams of water are added to  $M$  grams of solution containing  $N$  gram-molecular-weights of the alcohol per 1000 g of  $\text{H}_2\text{O}$  the heat ( $Q$ ) evolved per mole of water added is given by

$$Q = A - 10^{-3} \times Bm, \text{ g-cal}_{20}/\text{Mole}$$

$$Q = a - 10^{-3} \times bm, \text{ joule}/\text{Mole}$$

up to  $m = 800$  g. All weights *in vacuo*.  $t = 25^\circ\text{C}$ . Braham, Atmospheric Nitrogen Corporation, Syracuse, N. Y., O. MacInnes and Braham, *I*, 39: 2110; 17.

$N$	$\text{C}_2\text{H}_5\text{OH}, M = 9611 \text{ g}^*$				$\text{CH}_3\text{OH}, M = 9600 \text{ g}^\dagger$			
	A	B	a	b	A	B	a	b
1	2.00	0.51	8.37	2.13	1.10	0.00	4.22	0.00
2	8.80	1.38	36.8	5.78	4.44	0.21	18.6	0.88
3	21.85	2.481	91.4	10.38	10.30	0.825	43.10	3.45
4	40.60	4.450	170.0	18.63	18.53	1.8	77.5	

$$* A = 0.56N + 0.80N^2 + 0.72N^3 - 0.08N^4.$$

$$a = 2.348N + 3.35N^2 + 3.01N^3 - 0.335N^4.$$

$$\dagger A = -0.20N + 1.21N^2.$$

$$a = -0.837N + 5.03N^2.$$

## HEATS OF COMBUSTION OF ORGANIC COMPOUNDS

## Source of the Data

All of the values given in this section have been taken from the critical compilation by Kharasch (1) to which the reader is referred for bibliography and critical discussion.

## Units

The values recorded in the tables are expressed in 1922 International Combustion Calories<sup>1</sup> per gram-formula-weight (*in vacuo*) of substance in the liquid state (unless otherwise indicated by  $g$  = gas and  $s$  = solid) when the combustion takes place at constant pressure (1 atm.) and at  $18 - 20^\circ\text{C}$ , to form gaseous  $\text{CO}_2$  and  $\text{N}_2$ , liquid  $\text{H}_2\text{O}$ , and such compounds of other elements present as are indicated under the individual entries.

## Standard Substances for Combustion Calorimetry

**Primary Standard.**—The Third Conference of the International Union of Pure and Applied Chemistry (Lyons, 1922) adopted the benzoic acid standard with the following values:  $Q = 6324 \text{ g-cal}_{18}$  ( $= 26466 \text{ abs. j.}$ ) per gram in air;  $= 6319 \text{ g-cal}_{18}$  ( $= 26445 \text{ abs. j.}$ ) per gram *in vacuo*; cf. (3, 5). These values define what may be called the "1922 International Combustion Calorie."

<sup>1</sup> Calories instead of joules have been employed in this section in deference to the wishes of the Committee on Thermochemistry of the International Union of Pure and Applied Chemistry.

**Proposed Secondary Standard.**—Salicylic acid,  $Q = 5242 \text{ g-cal}_{18}$  ( $= 22699 \text{ abs. j.}$ ) per gram in air;  $= 5238 \text{ g-cal}_{18}$  ( $= 21921 \text{ abs. j.}$ ) per gram *in vacuo* (4).

**Other Standards.**—The best values for cane sugar and naphthalene may be obtained from the following carefully determined ratios of  $Q$  per gram in air (2).

$$\frac{\text{Naphthalene}}{\text{Benzoic acid}} = 1.5201. \quad \frac{\text{Benzoic acid}}{\text{Sugar}} = 1.6028. \quad \frac{\text{Naph.}}{\text{Sugar}} = 2.4364$$

## Calculation of Heat of Combustion from Structural Formula

The heat of combustion of any organic compound in the liquid state may be calculated from its structural formula with an accuracy, in most cases, of better than 1%. For most purposes for which heats of combustion are required this accuracy is sufficient. Indeed it is equal to or better than the accuracy of most of the experimental values now available. For a full description of the method of calculation and comparison between observed and calculated values, see (1).

## Heats of Formation

The heat of formation,  $H$ , of any compound ( $\text{C}_x\text{H}_y\text{Br}_z\text{Cl}_w\text{F}_v\text{I}_u\text{N}_p\text{O}_q\text{S}_r$ ) out of its elements in their standard states (*v. p.* 169) may be calculated from its heat of combustion,  $Q$ , as given below, by means of the equation  $H = (-Q + 94.38a + 34.19b +$



$0 \times c + 0 \times d + 75.6e + 0 \times f + 0 \times g + 0 \times h + 69.3i$  kg-cal<sub>18</sub>.

This equation applies where the products of combustion are CO<sub>2</sub>(g), H<sub>2</sub>O(l), Br<sub>2</sub>(l), Cl<sub>2</sub>(g), HF dilute aqueous solution, I<sub>2</sub>(s), N<sub>2</sub>(g), SO<sub>2</sub>(g). If the products of combustion are:

HBr(aq), the numerical coefficient of *c* is 28.54.

HCl(aq), the numerical coefficient of *d* is 39.46.

HNO<sub>3</sub>(aq), the numerical coefficient of *g* is 49.80.

H<sub>2</sub>SO<sub>4</sub>(aq), the numerical coefficient of *i* is 207.5.

To obtain *H* in kj per g.f.w. multiply by 4.185 the value given by the above equation.

### Tables

The compounds are arranged in groups as follows:

1. (C, H), Hydrocarbons.
2. (C, H, O), Alcohols (carbinols).
3. (C, H, O), Carboxylic acids.
4. (C, H, O), Acid anhydrides and lactones.
5. (C, H, O), Carbohydrates (sugars, starch, cellulose, etc.).
6. (C, H, O), Other C, H, O-compounds.
7. Nitrogen compounds.
8. Halogen compounds.
9. Sulfur compounds.

Formula	Name	kg-cal <sub>18</sub> per mole
1. HYDROCARBONS		
CH <sub>4</sub>	Methane (g)	210.8*
C <sub>2</sub> H <sub>2</sub>	Acetylene (ethine) (g)	312.0
C <sub>2</sub> H <sub>4</sub>	Ethylene (g)	33.2
C <sub>2</sub> H <sub>6</sub>	Ethane (g)	368.4†
C <sub>3</sub> H <sub>4</sub>	Allylene (propyne) (g)	456.1‡
		473.0§
C <sub>3</sub> H <sub>6</sub>	Propylene	490.2
C <sub>3</sub> H <sub>8</sub>	Trimethylene (g)	496.8
C <sub>3</sub> H <sub>8</sub>	Propane (g)	526.3
C <sub>3</sub> H <sub>8</sub>	Isobutylene (g)	647.2
C <sub>4</sub> H <sub>10</sub>	Isobutane (trimethylmethane) (g)	683.4¶
C <sub>4</sub> H <sub>10</sub>	Amylene	803.4
C <sub>5</sub> H <sub>10</sub>	Cyclopentane	783.6
C <sub>5</sub> H <sub>10</sub>	Methylcyclobutane	784.2
C <sub>5</sub> H <sub>12</sub>	Trimethylethylene (g)	803.6
	(liquid)	796.0
C <sub>5</sub> H <sub>12</sub>	Isopentane (g)	843.5
C <sub>5</sub> H <sub>12</sub>	(liquid)	838.3
C <sub>5</sub> H <sub>12</sub>	n-Pentane (g)	838.3
C <sub>5</sub> H <sub>12</sub>	(liquid)	833.4
C <sub>5</sub> H <sub>12</sub>	Tetramethylmethane	842.6(?)
C <sub>6</sub> H <sub>6</sub>	Benzene (g)	787.2
C <sub>6</sub> H <sub>6</sub>	(liquid)	783.4
C <sub>6</sub> H <sub>6</sub>	Dimethyldiacetylene (2, 4-hexadiene)	847.8
C <sub>6</sub> H <sub>6</sub>	Dipropargyl (1, 5-hexadiene)	853.5**
		882.9††
C <sub>6</sub> H <sub>6</sub>	Dihydrobenzene	833.2‡‡
		847.8§§
C <sub>6</sub> H <sub>10</sub>	Bicyclohexane (0, 1, 3)	912.5
C <sub>6</sub> H <sub>10</sub>	Diallyl (g)	928.1††
		903.4**
C <sub>6</sub> H <sub>10</sub>	Dimethylmethylenecyclopropane	898.0
C <sub>6</sub> H <sub>10</sub>	Tetrahydrobenzene (cyclohexene)	892
C <sub>6</sub> H <sub>12</sub>	Cyclohexane	939
C <sub>6</sub> H <sub>12</sub>	Hexylene	952.6
C <sub>6</sub> H <sub>12</sub>	Methylcyclopentane	937.9
C <sub>6</sub> H <sub>14</sub>	Diisopropyl (g)	993.9
C <sub>6</sub> H <sub>14</sub>	n-Hexane	990.6
C <sub>7</sub> H <sub>8</sub>	Toluene	936
C <sub>7</sub> H <sub>12</sub>	Bicycloheptane	1030.2
C <sub>7</sub> H <sub>12</sub>	Cycloheptane	1049.9
C <sub>7</sub> H <sub>12</sub>	Heptene-1	1091.2
C <sub>7</sub> H <sub>12</sub>	Methylenecyclohexane	1050
C <sub>7</sub> H <sub>14</sub>	1-Methyl-3-cyclohexene	1043.6

\* Average of nine determinations, max. d. = 1.1 %.

† Max. d. = 1.1 %.

‡ Thomsen.

§ Berthelot.

|| Max. d. = 0.9 %.

¶ Max. d. = 0.4 %.

\*\* Berthelot.

†† Thomsen.

‡‡ Swietoslowski.

Formula	Name	kg-cal <sub>18</sub> per mole
C <sub>7</sub> H <sub>14</sub>	1-Methyl-1-cyclohexene	1040.9‡‡
		1048.1
C <sub>7</sub> H <sub>14</sub>	Cycloheptane	1087.2
C <sub>7</sub> H <sub>14</sub>	1, 3-Dimethylcyclopentane	1090.7
C <sub>7</sub> H <sub>14</sub>	Methylcyclohexane	1091.8
C <sub>7</sub> H <sub>16</sub>	2, 2-Dimethylpentane	1148.9
C <sub>7</sub> H <sub>16</sub>	2, 3-Dimethylpentane	1148.9
C <sub>7</sub> H <sub>16</sub>	2, 4-Dimethylpentane	1148.9
C <sub>7</sub> H <sub>16</sub>	3, 3-Dimethylpentane	1147.9
C <sub>7</sub> H <sub>16</sub>	3-Ethylpentane	1149.9
C <sub>7</sub> H <sub>16</sub>	n-Heptane	1149.9
C <sub>7</sub> H <sub>16</sub>	2-Methylhexane	1148.9
C <sub>7</sub> H <sub>16</sub>	3-Methylhexane	1148.9
C <sub>7</sub> H <sub>16</sub>	2, 2, 3-Trimethylbutane	1147.9
C <sub>8</sub> H <sub>6</sub>	Phenylacetylene (phenylethine)	1024.2
C <sub>8</sub> H <sub>6</sub>	Styrene (phenylethylene)	1046
C <sub>8</sub> H <sub>10</sub>	Ethylbenzene	1091.2
C <sub>8</sub> H <sub>10</sub>	o-Xylene	1093
C <sub>8</sub> H <sub>10</sub>	m-Xylene	1089.6
C <sub>8</sub> H <sub>10</sub>	p-Xylene	1089.1
C <sub>8</sub> H <sub>12</sub>	1, 4-Dimethylcyclohexa-1, 3-diene	1152.2
C <sub>8</sub> H <sub>12</sub>	1, 3-Dimethyldihydrobenzene	1148.2
C <sub>8</sub> H <sub>12</sub>	1, Methyl-3-methylene-1-cyclohexene	1149.2
C <sub>8</sub> H <sub>14</sub>	1, 3-Dimethyl-3-cyclohexene	1194.5
C <sub>8</sub> H <sub>14</sub>	Ethylenecyclohexane	1207.7
C <sub>8</sub> H <sub>14</sub>	1-Ethyl-1-cyclohexene	1203.7
C <sub>8</sub> H <sub>14</sub>	Laurolene	1192.7
C <sub>8</sub> H <sub>14</sub>	i-Laurolene (1, 1, 2-trimethylcyclopent-2-ene)	1193.2
C <sub>8</sub> H <sub>16</sub>	1, 1-Dimethylcyclohexane	1242.5
C <sub>8</sub> H <sub>16</sub>	1, 3-Dimethylcyclohexane	1238(?)
C <sub>8</sub> H <sub>16</sub>	1, 4-Dimethylcyclohexane	1229(?)
C <sub>8</sub> H <sub>16</sub>	Diisobutylene	1252.4
C <sub>8</sub> H <sub>16</sub>	Methylcycloheptane	1244.5
C <sub>8</sub> H <sub>16</sub>	1, 2, 4-Trimethylcyclopentane	1245.4
C <sub>8</sub> H <sub>18</sub>	2, 5-Dimethylhexane	1303.2
C <sub>8</sub> H <sub>18</sub>	3, 4-Dimethylhexane	1303.7
C <sub>8</sub> H <sub>18</sub>	3-Ethylhexane	1302.2
C <sub>8</sub> H <sub>18</sub>	Hexamethylethane (s)	1301.6
C <sub>8</sub> H <sub>18</sub>	2-Methylheptane	1306.1
C <sub>8</sub> H <sub>18</sub>	n-Octane	1305
C <sub>8</sub> H <sub>18</sub>	2, 2, 4-Trimethylpentane	1303.9
C <sub>8</sub> H <sub>18</sub>	α-Methylstyrene	1202.9
C <sub>8</sub> H <sub>18</sub>	β-Methylstyrene (p-tolyethylene)	1202.4
C <sub>8</sub> H <sub>18</sub>	Isopropylbenzene	1247.2
C <sub>8</sub> H <sub>18</sub>	Mesitylene	1243.6
C <sub>8</sub> H <sub>18</sub>	n-Propylbenzene	1246.4
C <sub>8</sub> H <sub>18</sub>	Pseudocumene (1, 2, 4-trimethylbenzene)	1241.7
C <sub>8</sub> H <sub>18</sub>	1-Methyl-4-ethylcyclohexa-1, 3-diene	1310.2
C <sub>8</sub> H <sub>18</sub>	1-Isopropylcyclohex-1-ene	1340.2
C <sub>8</sub> H <sub>18</sub>	Ethylcycloheptane	1406.2
C <sub>8</sub> H <sub>18</sub>	Methyl-4-n-propylcyclopentane	1401.4
C <sub>8</sub> H <sub>18</sub>	1, 3, 3-Trimethylcyclohexane	1395(?)
C <sub>8</sub> H <sub>18</sub>	1, 2, 3-Trimethylcyclohexane	1396.0
C <sub>8</sub> H <sub>18</sub>	1, 3, 4-Trimethylcyclohexane	1383(?)
C <sub>10</sub> H <sub>8</sub>	Naphthalene (s)	1231.2
C <sub>10</sub> H <sub>8</sub>	Δ <sup>1</sup> -Dihydronaphthalene	1306
C <sub>10</sub> H <sub>8</sub>	Δ <sup>2</sup> -Dihydronaphthalene (s)	1298.2
C <sub>10</sub> H <sub>10</sub>	1-Phenyl-3-butene	1340.0
C <sub>10</sub> H <sub>10</sub>	α-β-Dimethylstyrene (s)	1357.2
C <sub>10</sub> H <sub>10</sub>	β-Ethylstyrene	1346.1
C <sub>10</sub> H <sub>12</sub>	1-Phenyl-3-butene	1356.9
C <sub>10</sub> H <sub>12</sub>	1-Phenyl-2-butene	1361.2
C <sub>10</sub> H <sub>12</sub>	Tetrahydronaphthalene	1340
C <sub>10</sub> H <sub>14</sub>	tert.-Butylbenzene	1400.4
C <sub>10</sub> H <sub>14</sub>	Hexahydronaphthalene	1419.2
C <sub>10</sub> H <sub>14</sub>	4-Isopropyltoluene (cymene)	1405
C <sub>10</sub> H <sub>14</sub>	3-n-Propyltoluene	1405
C <sub>10</sub> H <sub>14</sub>	3-Isopropyltoluene	1409
C <sub>10</sub> H <sub>14</sub>	1, 2, 4, 5-Tetramethylbenzene (durol) (s)	1393.6
C <sub>10</sub> H <sub>16</sub>	Borneocamphene	1470.2
C <sub>10</sub> H <sub>16</sub>	Camphene (s)	1468
C <sub>10</sub> H <sub>16</sub>	d-"Citrene"	1473.0
C <sub>10</sub> H <sub>16</sub>	Cyclene (tricyclene) (s)	1467.2
C <sub>10</sub> H <sub>16</sub>	1, 5-Dimethyl-3-vinyl-1-cyclohexene	1455.7
C <sub>10</sub> H <sub>16</sub>	1-Isobutenyl-1-cyclohexene	1461.2
C <sub>10</sub> H <sub>16</sub>	d-Limonene	1471.2
C <sub>10</sub> H <sub>16</sub>	l-Limonene	1457.2
C <sub>10</sub> H <sub>16</sub>	1-Methyl-4-isopropylcyclohexa-1, 3-diene	1470.7

§§ Stohmann.

||| Roth and Auwers.



Formula	Name	kg-cal <sub>15</sub> per mole
1. HYDROCARBONS.—(Continued)		
C <sub>10</sub> H <sub>16</sub>	Octahydronaphthalene	1461.7
C <sub>10</sub> H <sub>16</sub>	<i>d</i> - $\alpha$ -Pinene (australene)	1471.9
C <sub>10</sub> H <sub>16</sub>	<i>l</i> - $\alpha$ -Pinene (terebenthene)	1477
C <sub>10</sub> H <sub>16</sub>	$\beta$ -Pinolene	1469.8
C <sub>10</sub> H <sub>16</sub>	Sylvestrene	1464.7
C <sub>10</sub> H <sub>16</sub>	Terecamphene (inact.)	1466.7
C <sub>10</sub> H <sub>16</sub>	$\alpha$ -Terpinene	1470.4
C <sub>10</sub> H <sub>16</sub>	<i>cis</i> -Decahydronaphthalene	1502.8
C <sub>10</sub> H <sub>16</sub>	<i>trans</i> -Decahydronaphthalene	1498
C <sub>10</sub> H <sub>16</sub>	1-Ethyl-5-dimethylcyclohexene	1504.8
C <sub>10</sub> H <sub>16</sub>	Fenchane	1502.8
C <sub>10</sub> H <sub>16</sub>	Menthene ( $\Delta^1$ -terpene) ( $\Delta^1$ -menthene)	1523.2
C <sub>10</sub> H <sub>16</sub>	Thujane	1506.4
C <sub>10</sub> H <sub>16</sub>	Diamylene	1582.2
C <sub>10</sub> H <sub>16</sub>	<i>p</i> -Menthane (1-isopropyl-4-methylcyclohexane)	1514(?)
C <sub>10</sub> H <sub>16</sub>	Methyl-4- <i>n</i> -propyl-3-cyclohexane	1502.9
C <sub>10</sub> H <sub>16</sub>	Decane	1610.2
C <sub>10</sub> H <sub>16</sub>	Diisoamyl	1615.8
C <sub>11</sub> H <sub>18</sub>	1-Phenyl-2-pentene	1510.0
C <sub>11</sub> H <sub>18</sub>	Pentamethylbenzene ( <i>s</i> )	1554.0
C <sub>11</sub> H <sub>18</sub>	1, 5-Dimethyl-3-isopropene-1-cyclohexene	1615.0
C <sub>11</sub> H <sub>18</sub>	Acenaphthene ( <i>s</i> ) (periethylenenaphthylene)	1491.8
C <sub>11</sub> H <sub>18</sub>	Diphenyl ( <i>s</i> )	1493.6
C <sub>11</sub> H <sub>18</sub>	$\beta$ , $\beta$ -Diethylstyrene	1664.9
C <sub>11</sub> H <sub>18</sub>	Hexamethylbenzene ( <i>s</i> )	1711.9
C <sub>11</sub> H <sub>18</sub>	Triisobutylene [(CH <sub>3</sub> ) <sub>2</sub> CHC(CH <sub>3</sub> ) <sub>2</sub> CH(CH <sub>3</sub> ) <sub>2</sub> ] CHCH(CH <sub>3</sub> ) <sub>2</sub>	1858.8
C <sub>12</sub> H <sub>18</sub>	Fluorene ( <i>s</i> )	1584.9
C <sub>12</sub> H <sub>18</sub>	Diphenylmethane ( <i>s</i> )	1655.0
C <sub>12</sub> H <sub>18</sub>	Anthracene ( <i>s</i> )	1695
C <sub>12</sub> H <sub>18</sub>	Phenanthrene ( <i>s</i> )	1693
C <sub>12</sub> H <sub>18</sub>	Stilbene ( <i>sym</i> -diphenylethylene) ( <i>s</i> )	1765.0
C <sub>12</sub> H <sub>18</sub>	Isostilbene	1770.9
C <sub>12</sub> H <sub>18</sub>	Dibenzyl ( <i>s</i> )	1810.6
C <sub>12</sub> H <sub>18</sub>	3, 3-Dimethyldicyclohexyl( <i>m</i> -hexahydroditolyl)	2106
C <sub>12</sub> H <sub>18</sub>	$\alpha$ - $\beta$ -Methylphenylstyrene ( <i>s</i> )	1929
C <sub>12</sub> H <sub>18</sub>	Diphenyldiacetylene ( <i>s</i> )	1975.6
C <sub>12</sub> H <sub>18</sub>	Diphenylbutadiene ( <i>s</i> )	2057
C <sub>12</sub> H <sub>18</sub>	<i>cis-cis</i> -Diphenylbutadiene ( <i>s</i> )	2035
C <sub>12</sub> H <sub>18</sub>	<i>trans-trans</i> -Diphenylbutadiene ( <i>s</i> )	2030
C <sub>12</sub> H <sub>18</sub>	Hexadecane ( <i>s</i> )	2559
C <sub>12</sub> H <sub>18</sub>	Chrysene ( <i>s</i> )	2139
C <sub>12</sub> H <sub>18</sub>	Diphenylhexatriene ( <i>s</i> )	2288(?)
C <sub>12</sub> H <sub>18</sub>	Dibenzylbutadiene ( <i>s</i> )	2341
C <sub>12</sub> H <sub>18</sub>	1, 6-Diphenylhexa-1, 5-diene ( <i>s</i> )	2342
C <sub>12</sub> H <sub>18</sub>	Retene ( <i>s</i> ) (methylisopropylphenanthrene)	2307
C <sub>12</sub> H <sub>18</sub>	1, 4-Diphenyl-1-ethyl-3-butene	2372
C <sub>12</sub> H <sub>18</sub>	Triphenylmethyl ( <i>s</i> )	2378
C <sub>12</sub> H <sub>18</sub>	Triphenylmethane ( <i>s</i> )	2384
C <sub>12</sub> H <sub>18</sub>	Diphenylstyrene ( <i>s</i> )	2496
C <sub>12</sub> H <sub>18</sub>	Elcosane ( <i>s</i> )	3183
C <sub>12</sub> H <sub>18</sub>	1, 3, 5-Triphenylbenzene ( <i>s</i> )	2937
C <sub>12</sub> H <sub>18</sub>	Tetraphenylmethane ( <i>s</i> )	3102
C <sub>12</sub> H <sub>18</sub>	Dianthracene ( <i>s</i> )	3383

## 2. ALCOHOLS

CH <sub>4</sub> O	Methyl alcohol	170.9
C <sub>2</sub> H <sub>6</sub> O	Ethyl alcohol	328
C <sub>2</sub> H <sub>6</sub> O <sub>2</sub>	Glycol	281.9
C <sub>3</sub> H <sub>8</sub> O	Propargyl alcohol ( <i>g</i> )	428.9
C <sub>3</sub> H <sub>8</sub> O	Allyl alcohol	442.4
C <sub>3</sub> H <sub>8</sub> O	<i>n</i> -Propyl alcohol	482
C <sub>3</sub> H <sub>8</sub> O	Isopropyl alcohol	474.8
C <sub>3</sub> H <sub>8</sub> O <sub>2</sub>	Propylene glycol	431.0
C <sub>3</sub> H <sub>8</sub> O <sub>2</sub>	Isopropylene glycol	436.1
C <sub>3</sub> H <sub>8</sub> O <sub>2</sub>	Glycerol	397.0
C <sub>4</sub> H <sub>10</sub> O	<i>n</i> -Butyl alcohol	639
C <sub>4</sub> H <sub>10</sub> O	Isobutyl alcohol (primary)	638.2
C <sub>4</sub> H <sub>10</sub> O	Trimethyl carbinol ( <i>tert</i> -butyl)	629.3
C <sub>4</sub> H <sub>10</sub> O <sub>2</sub>	Diethylene glycol	567
C <sub>4</sub> H <sub>10</sub> O <sub>2</sub>	Erythritol ( <i>s</i> )	504.1
C <sub>4</sub> H <sub>10</sub> O	Cyclobutyl carbinol	748
C <sub>4</sub> H <sub>10</sub> O	Ethyl vinyl carbinol	753
C <sub>4</sub> H <sub>10</sub> O <sub>2</sub>	Dihydroxymethylcyclopropane	708
C <sub>4</sub> H <sub>10</sub> O <sub>2</sub>	Cyclopentan-1, 2-diol ( <i>cis</i> )	696.1
C <sub>4</sub> H <sub>10</sub> O <sub>2</sub>	Cyclopentan-1, 2-diol ( <i>trans</i> )	694.3
C <sub>4</sub> H <sub>10</sub> O	Amyl alcohol (?)	787
C <sub>4</sub> H <sub>10</sub> O	Amyl alcohol ( <i>ferm.</i> )*	792
C <sub>4</sub> H <sub>10</sub> O	Dimethyl ethyl carbinol	785

\* Mostly isobutyl carbinol.

Formula	Name	kg-cal <sub>15</sub> per mole
C <sub>5</sub> H <sub>12</sub> O <sub>4</sub>	Pentaerythritol ( <i>s</i> )	661
C <sub>5</sub> H <sub>12</sub> O <sub>5</sub>	Arabitol ( <i>s</i> )	612
C <sub>5</sub> H <sub>12</sub> O	Allyldimethyl carbinol	886.8†
		913.7‡
C <sub>6</sub> H <sub>12</sub> O	Cyclohexanol	891
C <sub>6</sub> H <sub>12</sub> O	$\beta$ -Methylcyclopentanol	888
C <sub>6</sub> H <sub>12</sub> O <sub>2</sub>	Cyclohexan-1, 2-diol ( <i>cis</i> )	841.6
C <sub>6</sub> H <sub>12</sub> O <sub>2</sub>	Cyclohexan-1, 2-diol ( <i>trans</i> )	842.7
C <sub>6</sub> H <sub>12</sub> O <sub>3</sub>	Quercitol ( <i>s</i> )	704
C <sub>6</sub> H <sub>12</sub> O <sub>3</sub>	Inositol (inosite) ( <i>s</i> )	662
C <sub>6</sub> H <sub>14</sub> O	Pinacolyl alcohol	939
C <sub>6</sub> H <sub>14</sub> O	Methyldiethyl carbinol	927
C <sub>6</sub> H <sub>14</sub> O <sub>2</sub>	Pinacol ( <i>s</i> )	897.6
C <sub>6</sub> H <sub>14</sub> O <sub>3</sub>	Dulcitol ( <i>s</i> )	729.1§
		723.7
C <sub>6</sub> H <sub>14</sub> O <sub>6</sub>	<i>d</i> -Mannitol ( <i>s</i> )	727.6
C <sub>7</sub> H <sub>16</sub> O	Benzyl alcohol	893
C <sub>7</sub> H <sub>16</sub> O	Diallyl carbinol	1028
C <sub>7</sub> H <sub>16</sub> O	Allylmethylethyl carbinol	1050.1
C <sub>7</sub> H <sub>16</sub> O	Cycloheptanol	1050.2
C <sub>7</sub> H <sub>16</sub> O	Cyclohexyl carbinol	1047.2
C <sub>7</sub> H <sub>16</sub> O	1, 3-Dimethylcyclopentan-2-ol	1030.6
C <sub>7</sub> H <sub>16</sub> O	1, 3-Dimethylcyclopentan-3-ol	1034.6
C <sub>7</sub> H <sub>16</sub> O	1-Ethylcyclopentan-2-ol	1039
C <sub>7</sub> H <sub>16</sub> O	$\beta$ -Methylcyclohexanol	1038
C <sub>7</sub> H <sub>16</sub> O <sub>2</sub>	<i>cis</i> -1-Methylcyclohexan-1, 2-diol	992.6
	<i>trans</i> -1-Methylcyclohexan-1, 2-diol	995.1
C <sub>7</sub> H <sub>16</sub> O	<i>n</i> -Heptyl alcohol	1104.9
C <sub>7</sub> H <sub>16</sub> O	Triethyl carbinol	1080
C <sub>7</sub> H <sub>16</sub> O <sub>7</sub>	Perseitol ( <i>d</i> -mannoheptol) ( <i>s</i> )	836
C <sub>8</sub> H <sub>16</sub> O	Amylpropargyl alcohol	1192
C <sub>8</sub> H <sub>16</sub> O	Diallylmethyl carbinol	1181
C <sub>8</sub> H <sub>16</sub> O <sub>2</sub>	Tetramethylbutindiol	1142
C <sub>8</sub> H <sub>16</sub> O	Allyldiethyl carbinol	1207
C <sub>8</sub> H <sub>16</sub> O	Allylmethylpropyl carbinol	1202
C <sub>8</sub> H <sub>16</sub> O	1, 2-Dimethylcyclohexan-2-ol	1196.8
C <sub>8</sub> H <sub>16</sub> O	1, 3-Dimethylcyclohexan-2-ol	1196
C <sub>8</sub> H <sub>16</sub> O	1, 3-Dimethylcyclohexan-3-ol	1192.8
C <sub>8</sub> H <sub>16</sub> O	1, 3-Dimethylcyclohexan-5-ol	1183
C <sub>8</sub> H <sub>16</sub> O <sub>2</sub>	Tetramethylbutenediol (fumaroid)	1176
C <sub>8</sub> H <sub>16</sub> O <sub>2</sub>	Tetramethylbutenediol (maleinoid) ( <i>s</i> )	1172
C <sub>8</sub> H <sub>16</sub> O	Octyl alcohol	1262
C <sub>8</sub> H <sub>16</sub> O	Methyldipropyl carbinol	1233
C <sub>8</sub> H <sub>16</sub> O	Phenylpropargyl alcohol**	1137
C <sub>8</sub> H <sub>16</sub> O <sub>2</sub>	Hydrinden-1, 2-diol ( <i>cis</i> )	1098.8
C <sub>8</sub> H <sub>16</sub> O <sub>2</sub>	Hydrinden-1, 2-diol ( <i>trans</i> )	1096.7
C <sub>8</sub> H <sub>16</sub> O	Hexylpropargyl alcohol	1340
C <sub>8</sub> H <sub>16</sub> O	1, 3, 5-Trimethylcyclohex-6-en-5-ol	1295
C <sub>8</sub> H <sub>16</sub> O	Allylmethyl- <i>n</i> -butyl carbinol	1365
C <sub>8</sub> H <sub>16</sub> O	Allylmethyl- <i>tert</i> -butyl carbinol	1363
C <sub>8</sub> H <sub>16</sub> O	Cycloheptylmethyl carbinol	1342
C <sub>8</sub> H <sub>16</sub> O	1-Methyl-3-ethylcyclohexan-3-ol	1322
C <sub>8</sub> H <sub>16</sub> O <sub>2</sub>	Ethyldipropyl carbinol	1386.8
C <sub>10</sub> H <sub>18</sub> O <sub>2</sub>	1, 2, 3, 4-Tetrahydronaphthalenediols, all forms	1250
C <sub>10</sub> H <sub>18</sub> O	Borneol (synthetic)	1466
C <sub>10</sub> H <sub>18</sub> O	Borneol (Borneo camphor)	1470
C <sub>10</sub> H <sub>18</sub> O	$\alpha$ -Borneol ( <i>s</i> )	1466.6
C <sub>10</sub> H <sub>18</sub> O	<i>l</i> -Borneol	1467.2
C <sub>10</sub> H <sub>18</sub> O	Diallylpropyl carbinol	1472
C <sub>10</sub> H <sub>18</sub> O	Terpineol ( <i>s</i> )	1469 to 1480
C <sub>10</sub> H <sub>18</sub> O	Thujyl alcohol	1477.8
C <sub>10</sub> H <sub>18</sub> O	Allyldipropyl carbinol	1518.0††
		1549.8‡‡
C <sub>10</sub> H <sub>18</sub> O	Menthol ( <i>s</i> )	1509
C <sub>10</sub> H <sub>18</sub> O <sub>2</sub>	Terpinehydrate ( <i>s</i> )	1451
C <sub>11</sub> H <sub>22</sub> O	Allylmethylhexyl carbinol	1667
C <sub>11</sub> H <sub>22</sub> O <sub>2</sub>	1-Phenylcyclohexan-1, 2-diol ( <i>cis</i> and <i>trans</i> )	1564
C <sub>11</sub> H <sub>22</sub> O	Diphenyl carbinol ( <i>s</i> )	1615
C <sub>11</sub> H <sub>22</sub> O <sub>2</sub>	Hydrobenzoin ( <i>s</i> )	1723
C <sub>11</sub> H <sub>22</sub> O <sub>2</sub>	Isosydrobenzoin ( <i>s</i> )	1728
C <sub>11</sub> H <sub>22</sub> O	Amylphenylpropargyl alcohol	1901
C <sub>11</sub> H <sub>22</sub> O	Cetyl alcohol ( <i>s</i> )	2504
C <sub>11</sub> H <sub>22</sub> O	Triphenyl carbinol ( <i>s</i> )	2341
C <sub>11</sub> H <sub>22</sub> O	Diphenylphenylethynyl carbinol	2572

† Swietoslawski.

‡ Louguinine.

§ Berthelot.

|| Stohmann.

¶ C<sub>8</sub>H<sub>11</sub>.C:C.CH<sub>2</sub>OH.\*\* C<sub>8</sub>H<sub>5</sub>.C:C.CH<sub>2</sub>OH.

†† Swietoslawski.

‡‡ Louguinine.



Formula	Name	kg-cal. per mole
3. C, H, O, Acids		
$\text{CH}_2\text{O}_2$	Formic.....	62.8
$\text{C}_2\text{H}_2\text{O}_4$	Oxalic (s).....	60.15
$\text{C}_2\text{H}_4\text{O}_2$	Acetic.....	209.4*
		207.1†
$\text{C}_2\text{H}_4\text{O}_3$	Glycolic (s).....	166.6
$\text{C}_2\text{H}_4\text{O}_4$	Dihydroxyacetic (glyoxylic) (s).....	125.5
$\text{C}_3\text{H}_4\text{O}_2$	Acrylic.....	327.8
$\text{C}_3\text{H}_4\text{O}_3$	Pyroracemic, pyruvic.....	279.1
$\text{C}_3\text{H}_4\text{O}_4$	Malonic (s).....	206.8
$\text{C}_3\text{H}_4\text{O}_5$	Tartronic (s).....	165.4
$\text{C}_3\text{H}_4\text{O}_6$	Mesoxalic (dihydroxymalonic) (s).....	128.2
$\text{C}_3\text{H}_6\text{O}_2$	Propionic.....	365
$\text{C}_3\text{H}_6\text{O}_3$	Lactic (s).....	326.0
$\text{C}_4\text{H}_4\text{O}_4$	Acetylenedicarboxylic (s).....	305.9
$\text{C}_4\text{H}_4\text{O}_5$	Tetrollic (s).....	452.4
$\text{C}_4\text{H}_4\text{O}_6$	Fumaric (trans) (s).....	320.0
$\text{C}_4\text{H}_4\text{O}_7$	Maleic (cis) (s).....	326.1
$\text{C}_4\text{H}_6\text{O}_2$	Crotonic (s).....	477.7
$\text{C}_4\text{H}_6\text{O}_3$	Trimethylenecarboxylic.....	481
$\text{C}_4\text{H}_6\text{O}_4$	Methylmalonic (s).....	363.8
$\text{C}_4\text{H}_6\text{O}_5$	Succinic (s).....	356.8
$\text{C}_4\text{H}_6\text{O}_6$	l-Malic.....	320.1
$\text{C}_4\text{H}_6\text{O}_7$	d-Tartaric (s).....	275.1
$\text{C}_4\text{H}_6\text{O}_8$	dl-Tartaric (anhydr.) (s).....	273.0
$\text{C}_4\text{H}_8\text{O}_4$	Mesotartaric (s).....	276.0
$\text{C}_4\text{H}_8\text{O}_5$	n-Butyric.....	520
$\text{C}_4\text{H}_8\text{O}_6$	Isobutyric.....	517.4
$\text{C}_4\text{H}_8\text{O}_7$	Hydroxyisobutyric (s).....	471.8
$\text{C}_4\text{H}_8\text{O}_8$	dl-β-Hydroxybutyric (s).....	487.9
$\text{C}_4\text{H}_8\text{O}_9$	Pyromucic (s).....	489.7
$\text{C}_5\text{H}_8\text{O}_4$	cis-Citraconic (methylmaleic) (s).....	479.1
$\text{C}_5\text{H}_8\text{O}_5$	Itaconic (methylenesuccinic) (s).....	475.3
$\text{C}_5\text{H}_8\text{O}_6$	trans-Mesaconic (methylfumaric) (s).....	476.4
$\text{C}_5\text{H}_8\text{O}_7$	α, α-Trimethylenedicarboxylic (s).....	483
$\text{C}_5\text{H}_8\text{O}_8$	α, β-Trimethylenedicarboxylic (s).....	484
$\text{C}_5\text{H}_8\text{O}_9$	Allylacetic.....	641.6
$\text{C}_5\text{H}_8\text{O}_{10}$	Angellic (s).....	634.8
$\text{C}_5\text{H}_{10}\text{O}_4$	α, β-Pentenic (s).....	623.7
$\text{C}_5\text{H}_{10}\text{O}_5$	β, γ-Pentenic (s).....	632.2
$\text{C}_5\text{H}_{10}\text{O}_6$	Tetramethylenedicarboxylic.....	640
$\text{C}_5\text{H}_{10}\text{O}_7$	Tiglic (s).....	626.4
$\text{C}_5\text{H}_{10}\text{O}_8$	Levulinic (β-acetylpropionic) (s).....	576.8
$\text{C}_5\text{H}_{10}\text{O}_9$	Dimethylmalonic (s).....	515.1
$\text{C}_5\text{H}_{10}\text{O}_{10}$	Ethylmalonic (s).....	517.7
$\text{C}_5\text{H}_{10}\text{O}_{11}$	Glutaric (s).....	514.8
$\text{C}_5\text{H}_{10}\text{O}_{12}$	Methylsuccinic (s).....	515.3
$\text{C}_5\text{H}_{10}\text{O}_{13}$	Trihydroxyglutaric (s).....	388.3
$\text{C}_6\text{H}_{10}\text{O}_4$	n-Valeric.....	679
$\text{C}_6\text{H}_{10}\text{O}_5$	Aconitic (s).....	475.1
$\text{C}_6\text{H}_{10}\text{O}_6$	Sorbic (s).....	743
$\text{C}_6\text{H}_{10}\text{O}_7$	Allylmalonic (s).....	638
$\text{C}_6\text{H}_{10}\text{O}_8$	α, β-Hydromuconic (s).....	628.8
$\text{C}_6\text{H}_{10}\text{O}_9$	β, γ-Hydromuconic (s).....	629.1
$\text{C}_6\text{H}_{10}\text{O}_{10}$	α, α-Tetramethylenedicarboxylic (s).....	642.0
$\text{C}_6\text{H}_{10}\text{O}_{11}$	α, β-Tetramethylenedicarboxylic (s).....	642.1
$\text{C}_6\text{H}_{10}\text{O}_{12}$	α, γ-Tetramethylenedicarboxylic (s).....	639.4
$\text{C}_6\text{H}_{10}\text{O}_{13}$	Tricarballic (s).....	516.0
$\text{C}_6\text{H}_{10}\text{O}_{14}$	Citric (anhydr.) (s).....	474.5
$\text{C}_6\text{H}_{10}\text{O}_{15}$	Citric (cryst.) (s).....	471.4
$\text{C}_6\text{H}_{10}\text{O}_{16}$	Hydrosorbic.....	795
$\text{C}_6\text{H}_{10}\text{O}_{17}$	Adipic (s).....	668.8
$\text{C}_6\text{H}_{10}\text{O}_{18}$	sym.-Dimethylsuccinic (anti) (s).....	674.2
$\text{C}_6\text{H}_{10}\text{O}_{19}$	sym.-Dimethylsuccinic (anti) (s).....	673.0
$\text{C}_6\text{H}_{10}\text{O}_{20}$	dl-sym.-Dimethylsuccinic (s).....	671.5
$\text{C}_6\text{H}_{10}\text{O}_{21}$	sym.-Dimethylsuccinic (para) (s).....	670.6
$\text{C}_6\text{H}_{10}\text{O}_{22}$	unsym.-Dimethylsuccinic (s).....	671
$\text{C}_6\text{H}_{10}\text{O}_{23}$	Ethylsuccinic (s).....	671.2
$\text{C}_6\text{H}_{10}\text{O}_{24}$	Methylethylmalonic (s).....	672
$\text{C}_6\text{H}_{10}\text{O}_{25}$	α-Methylglutaric (s).....	670.6
$\text{C}_6\text{H}_{10}\text{O}_{26}$	Propylmalonic (s).....	674
$\text{C}_6\text{H}_{10}\text{O}_{27}$	Isopropylmalonic (s).....	674
$\text{C}_6\text{H}_{10}\text{O}_{28}$	Allomucic (s).....	494.2
$\text{C}_6\text{H}_{10}\text{O}_{29}$	Mucic (s).....	483.6
$\text{C}_6\text{H}_{10}\text{O}_{30}$	Caproic.....	831.0†
$\text{C}_6\text{H}_{10}\text{O}_{31}$	Diethylacetic.....	838.2‡
$\text{C}_6\text{H}_{10}\text{O}_{32}$		831

\* Berthelot.

† Roth.

‡ Sweitoslawski

§ Fischer and Wrede.

Formula	Name	kg-cal. per mole
$\text{C}_4\text{H}_8\text{O}_2$	Isobutylacetic.....	833
$\text{C}_7\text{H}_4\text{O}_7$	Meconic (s).....	490.8
$\text{C}_7\text{H}_6\text{O}_2$	Benzoic (s).....	711.2‡
$\text{C}_7\text{H}_6\text{O}_3$	Salicylic (s).....	723.1
$\text{C}_7\text{H}_6\text{O}_4$	m-Hydroxybenzoic (s).....	725.4
$\text{C}_7\text{H}_6\text{O}_5$	p-Hydroxybenzoic (s).....	724.6
$\text{C}_7\text{H}_6\text{O}_6$	2, 4-Dihydroxybenzoic (s).....	676.5
$\text{C}_7\text{H}_6\text{O}_7$	Gallic (s).....	633.7
$\text{C}_7\text{H}_6\text{O}_8$	Pyrogallolcarboxylic (s).....	633.4
$\text{C}_7\text{H}_6\text{O}_9$	α, α, β, β-Trimethylenetetracarboxylic (s).....	482.7
$\text{C}_7\text{H}_{10}\text{O}_2$	Δ <sup>1</sup> -Tetrahydrobenzoic (s).....	857
$\text{C}_7\text{H}_{10}\text{O}_3$	Δ <sup>2</sup> -Tetrahydrobenzoic (s).....	886
$\text{C}_7\text{H}_{10}\text{O}_4$	α, β-Pentamethylenedicarboxylic (s).....	781.5
$\text{C}_7\text{H}_{10}\text{O}_5$	Teraconic acid (γ-dimethylitaconic) (s).....	796
$\text{C}_7\text{H}_{12}\text{O}_2$	Hexahydrobenzoic.....	934
$\text{C}_7\text{H}_{12}\text{O}_3$	Diethylmalonic (s).....	829
$\text{C}_7\text{H}_{12}\text{O}_4$	Pimelic (isopropylsuccinic).....	827
$\text{C}_7\text{H}_{12}\text{O}_5$	Trimethylsuccinic (s).....	829.9
$\text{C}_7\text{H}_{14}\text{O}_2$	Ethylpropylacetic.....	990
$\text{C}_7\text{H}_{14}\text{O}_3$	Heptylic.....	986.1
$\text{C}_8\text{H}_6\text{O}_4$	o-Phthalic (s).....	771.0
$\text{C}_8\text{H}_6\text{O}_5$	Isophthalic (s).....	768.8
$\text{C}_8\text{H}_6\text{O}_6$	Terephthalic (s).....	770.4
$\text{C}_8\text{H}_6\text{O}_7$	Piperonylic (s).....	803.5
$\text{C}_8\text{H}_6\text{O}_8$	Phenylacetic (s).....	930
$\text{C}_8\text{H}_8\text{O}_2$	o-Toluic (s).....	928.9†
		921.0**
$\text{C}_8\text{H}_8\text{O}_3$	m-Toluic (s).....	928.6‡
		922.2**
$\text{C}_8\text{H}_8\text{O}_4$	p-Toluic (s).....	926.9‡
$\text{C}_8\text{H}_8\text{O}_5$	o-Hydroxymethylbenzoic (s).....	887.3
$\text{C}_8\text{H}_8\text{O}_6$	1, 2, 3-Hydroxytoluic†† (s).....	878.7
$\text{C}_8\text{H}_8\text{O}_7$	1, 2, 4-Hydroxytoluic†† (s).....	877.8
$\text{C}_8\text{H}_8\text{O}_8$	1, 2, 5-Hydroxytoluic†† (s).....	879.5
$\text{C}_8\text{H}_8\text{O}_9$	1, 2, 6-Hydroxytoluic†† (s).....	882.8
$\text{C}_8\text{H}_8\text{O}_{10}$	Mandelic (s).....	890
$\text{C}_8\text{H}_8\text{O}_{11}$	p-Methoxybenzoic (s).....	894.6
$\text{C}_8\text{H}_8\text{O}_{12}$	Phenoxyacetic (s).....	903
$\text{C}_8\text{H}_8\text{O}_{13}$	Dihydroterephthalic (s).....	842.6
$\text{C}_8\text{H}_8\text{O}_{14}$	Δ <sup>1,4</sup> -Dihydroterephthalic (s).....	835.6
$\text{C}_8\text{H}_8\text{O}_{15}$	Δ <sup>1,6</sup> -Dihydroterephthalic (s).....	842.1
$\text{C}_8\text{H}_8\text{O}_{16}$	Δ <sup>2,6</sup> -Dihydroterephthalic (fum.) (s).....	844.9
$\text{C}_8\text{H}_{10}\text{O}_4$	Δ <sup>1</sup> -Tetrahydroterephthalic (s).....	882
$\text{C}_8\text{H}_{10}\text{O}_5$	Δ <sup>2</sup> -Tetrahydroterephthalic (s).....	881
$\text{C}_8\text{H}_{12}\text{O}_2$	Amylpropionic.....	1083
$\text{C}_8\text{H}_{12}\text{O}_3$	Cyclohexene-1-acetic (s).....	1045
$\text{C}_8\text{H}_{12}\text{O}_4$	Cyclohexylideneacetic (s).....	1042
$\text{C}_8\text{H}_{12}\text{O}_5$	trans-1, 2-Cyclohexanedicarboxylic (s).....	930
$\text{C}_8\text{H}_{12}\text{O}_6$	cis-Hexahydroterephthalic (s).....	928.2
$\text{C}_8\text{H}_{12}\text{O}_7$	trans-Hexahydroterephthalic (s).....	929.1
$\text{C}_8\text{H}_{12}\text{O}_8$	Cycloheptanecarboxylic (s).....	1088
$\text{C}_8\text{H}_{12}\text{O}_9$	Cyclooctane (act.)†.....	1089.2
$\text{C}_8\text{H}_{12}\text{O}_{10}$	Hexahydro-m-toluic.....	1086
$\text{C}_8\text{H}_{12}\text{O}_{11}$	sym.-Diethylsuccinic (s).....	987
$\text{C}_8\text{H}_{12}\text{O}_{12}$	unsym.-Diethylsuccinic (s).....	985
$\text{C}_8\text{H}_{12}\text{O}_{13}$	sym.-Dimethyladipic (s).....	986.7
$\text{C}_8\text{H}_{12}\text{O}_{14}$	Ethylpropylmalonic (s).....	983
$\text{C}_8\text{H}_{12}\text{O}_{15}$	Suberic (s).....	983.4
$\text{C}_8\text{H}_{12}\text{O}_{16}$	Tetramethylsuccinic (s).....	989
$\text{C}_8\text{H}_{12}\text{O}_{17}$	Dimethyldihydroxyadipic (s).....	889
$\text{C}_8\text{H}_{12}\text{O}_{18}$	Dipropylacetic.....	1146
$\text{C}_8\text{H}_{12}\text{O}_{19}$	Phenylpropionic (s).....	1021
$\text{C}_8\text{H}_{12}\text{O}_{20}$	Trimelic (s).....	767.0
$\text{C}_8\text{H}_{12}\text{O}_{21}$	cis-Allocinnamic (M. P. 58°) (s).....	1047
$\text{C}_8\text{H}_{12}\text{O}_{22}$	trans-Cinnamic (s).....	1040
$\text{C}_8\text{H}_{12}\text{O}_{23}$	Atropic (s).....	1044
$\text{C}_8\text{H}_{12}\text{O}_{24}$	cis-(allo)-p-Hydroxycinnamic (s).....	996
$\text{C}_8\text{H}_{12}\text{O}_{25}$	trans-p-Hydroxycinnamic (s).....	991
$\text{C}_8\text{H}_{12}\text{O}_{26}$	Uvic (s).....	928.8
$\text{C}_8\text{H}_{12}\text{O}_{27}$	Hydrocinnamic (β-phenylpropionic) (s).....	1085
$\text{C}_8\text{H}_{12}\text{O}_{28}$	Mesitylenic (s).....	1085
$\text{C}_8\text{H}_{12}\text{O}_{29}$	α-Cyclohexene-1-propionic.....	1200
$\text{C}_8\text{H}_{12}\text{O}_{30}$	Hexylpropionic.....	1232
$\text{C}_8\text{H}_{14}\text{O}_2$	Campholytic (s).....	1366
$\text{C}_8\text{H}_{14}\text{O}_3$	Isocampholytic (s).....	1363

‡ p. 162.

† Stohmann.

\*\* Auwers and Roth.

†† The numbers denote the positions of carboxyl, hydroxyl and methyl groups respectively.



Formula	Name	kg-cal. per mole
3. C, H, O, Acids.—(Continued)		
$C_7H_{10}O_4$	Aselaic (s).....	1141.4
$C_7H_{10}O_4$	Dipropylmalonic (s).....	1140
$C_7H_{10}O_4$	Heptylacetic.....	1287
$C_{10}H_{16}O_4$	Pyromellitic (s).....	776.8
$C_{10}H_{16}O_4$	<i>cis</i> -Alloperonylacrylic (s).....	1076
$C_{10}H_{16}O_4$	<i>trans</i> -Piperonylacrylic (s).....	1067
$C_{10}H_{16}O_4$	Benzalmalonic (s).....	1056
$C_{10}H_{16}O_4$	$\alpha$ -Methylcinnamic (s).....	1198
$C_{10}H_{16}O_4$	$\beta$ -Methylcinnamic (s).....	1197
$C_{10}H_{16}O_4$	<i>cis</i> -Phenylisocrotonic†† (s).....	1195
$C_{10}H_{16}O_4$	<i>cis</i> -( <i>allo</i> )- <i>p</i> -Methoxycinnamic (s).....	1172
$C_{10}H_{16}O_4$	<i>trans</i> - <i>p</i> -Methoxycinnamic§§ (s).....	1163
$C_{10}H_{16}O_4$	<i>cis</i> -Methylcoumarinic (s).....	1167
$C_{10}H_{16}O_4$	<i>trans</i> -Methylcoumarinic (s).....	1161
$C_{10}H_{16}O_4$	Benzylmalonic (s).....	1082.5
$C_{10}H_{16}O_4$	Phenylsuccinic (s).....	1082.8
$C_{10}H_{16}O_4$	Opianic (s).....	1090
$C_{10}H_{16}O_4$	Hemipinic (s).....	1025
$C_{10}H_{16}O_4$	Cumic ( <i>p</i> -isopropylbenzoic) (s).....	1238
$C_{10}H_{16}O_4$	Geranic.....	1379
$C_{10}H_{16}O_4$	$\alpha$ -Tanacetoneketocarboxylic (s).....	1327
$C_{10}H_{16}O_4$	<i>d</i> -Camphoric (s).....	1244
$C_{10}H_{16}O_4$	Campholic (s).....	1412
$C_{10}H_{16}O_4$	Hexahydrocuminic (s).....	1396
$C_{10}H_{16}O_4$	Heptylmalonic (s).....	1297
$C_{10}H_{16}O_4$	Sebacic (s).....	1297
$C_{10}H_{16}O_4$	Triethylsuccinic (s).....	1301
$C_{10}H_{16}O_4$	Capric (s).....	1453
$C_{11}H_{18}O_4$	$\alpha$ -Naphthoic (s).....	1232
$C_{11}H_{18}O_4$	$\beta$ -Naphthoic.....	1227
$C_{11}H_{18}O_4$	Allocinnamylideneacetic (s).....	1319
$C_{11}H_{18}O_4$	Cinnamylideneacetic (s).....	1311
$C_{11}H_{18}O_4$	<i>cis</i> -Acetylcoumarinic (s).....	1212
$C_{11}H_{18}O_4$	<i>trans</i> -Acetylcoumarinic (s).....	1208
$C_{11}H_{18}O_4$	Phenylparaconic (s).....	1195
$C_{11}H_{18}O_4$	<i>cis</i> -Ethylcoumarinic (s).....	1323
$C_{11}H_{18}O_4$	<i>trans</i> -Ethylcoumarinic (M. P. 133–134°) (s).....	1316
$C_{11}H_{18}O_4$	Undecolic (s).....	1538
$C_{11}H_{18}O_4$	Undecylenic (s).....	1580
$C_{11}H_{18}O_4$	Nonanedicarboxylic (s).....	1456
$C_{11}H_{18}O_4$	<i>n</i> -Octylmalonic (s).....	1453
$C_{11}H_{18}O_4$	Undecylic (s).....	1610
$C_{12}H_{20}O_4$	Mellitic (s).....	788
$C_{12}H_{20}O_4$	Naphthalic (1, 8-naphthalenedicarboxylic) (s).....	1244
$C_{12}H_{20}O_4$	Cinnamylidenemalonic (yellow) (s).....	1319
$C_{12}H_{20}O_4$	$\beta$ -Benzallevulinic (s).....	1413
$C_{12}H_{20}O_4$	$\delta$ -Benzallevulinic (s).....	1410
$C_{12}H_{20}O_4$	Hexahydromellitic (fum.) (s).....	923
$C_{12}H_{20}O_4$	<i>cis</i> -Propylcoumarinic (s).....	1476
$C_{12}H_{20}O_4$	<i>trans</i> -Propylcoumarinic (s).....	1470
$C_{12}H_{20}O_4$	Decanedicarboxylic (s).....	1611
$C_{12}H_{20}O_4$	Tetraethylsuccinic (s).....	1619
$C_{12}H_{20}O_4$	Lauric (s).....	1772
$C_{12}H_{20}O_4$	<i>trans</i> - <i>n</i> -Butylcoumarinic (s).....	1631
$C_{12}H_{20}O_4$	<i>cis</i> - <i>n</i> -Butylcoumarinic (s).....	1637
$C_{12}H_{20}O_4$	Brassylic (undecanedicarboxylic) (s).....	1769
$C_{12}H_{20}O_4$	Diphenylacetic (s).....	1651
$C_{12}H_{20}O_4$	Benzilic (s).....	1618
$C_{12}H_{20}O_4$	Isoamylcoumarinic (s).....	1790
$C_{12}H_{20}O_4$	<i>cis</i> -Isoamylcoumarinic (s).....	1791
$C_{12}H_{20}O_4$	Myristic (s).....	2086
$C_{12}H_{20}O_4$	$\alpha$ -Diphenylsuccinic (anhydr.) (easily sol. form) (s)     .....	1810
$C_{12}H_{20}O_4$	$\beta$ -Diphenylsuccinic (difficultly sol.) (s).....	1087
$C_{12}H_{20}O_4$	Dibenzylacetic (s).....	1954
$C_{12}H_{20}O_4$	Palmitic (s).....	2380
$C_{12}H_{20}O_4$	$\beta$ -Tolylmethoxycinnamic (stable) (s).....	2035
$C_{12}H_{20}O_4$	$\alpha$ -Truxillic (s).....	2083
$C_{12}H_{20}O_4$	Stearolic (s).....	2629
$C_{12}H_{20}O_4$	Elaidic (s).....	2664
$C_{12}H_{20}O_4$	Oleic.....	2657†††
		2682***

††  $C_6H_5CH:CH.CH_2COOH$ .

§§ M. P. 170° (liq. cryst.); clears at 185°.

|| The heat of combustion of the acetone addition product of  $\alpha$ -diphenylsuccinic acid (easily sol. form) is given as 2237.9 kg-cal.

††† Emery and Benedict.

\*\*\* Stohmann.

††† Exposed to the action of light.

Formula	Name	kg-cal. per mole
$C_{18}H_{36}O_2$	Stearic (s).....	2698
$C_{18}H_{36}O_2$	Cetylmalonic (s).....	2898
$C_{20}H_{40}O_2$	Arachidic (s).....	3016
$C_{22}H_{44}O_2$	Behenolic.....	3255
$C_{22}H_{44}O_2$	Brassicic (s).....	3290
$C_{22}H_{44}O_2$	Erucic (s).....	3297
$C_{22}H_{44}O_2$	Behenic (s).....	3338
$C_{22}H_{44}O_4$	Dihydroxybehenic (s).....	3236
$C_{24}H_{48}O_4$	Cinnamylidenemalonic†††.....	2639

## 4. C, H, O, ACID ANHYDRIDES AND LACTONES

$C_4H_4O_3$	Maleic anhydride (s).....	333.9
$C_4H_4O_3$	Succinic anhydride (s).....	369.5
$C_4H_6O_3$	Acetic anhydride (g).....	458.3
	(liquid).....	431.9
$C_5H_6O_3$	Itaconic anhydride (s).....	481.5
$C_5H_6O_3$	Glutaric anhydride (s).....	528.0
$C_5H_6O_3$	Methylsuccinic anhydride (s).....	527.7
$C_5H_6O_3$	Dimethylsuccinic anhydride ( <i>sym.</i> ) (s).....	680
$C_5H_6O_3$	Dimethylsuccinic anhydride ( <i>unsym.</i> ) (s).....	682.6
$C_5H_6O_3$	Ethylsuccinic anhydride.....	684.8
$C_5H_{10}O_3$	Propionic anhydride.....	746.6
$C_5H_{10}O_3$	Saccharic acid lactone (s).....	656.6
$C_5H_{10}O_3$	<i>l</i> -Gulonolactone (s).....	614.7
$C_5H_{10}O_3$	<i>d</i> -Mannolactone (s).....	618.7
$C_5H_{10}O_3$	<i>l</i> -Mannolactone (s).....	616.8
$C_7H_{10}O_3$	Trimethylsuccinic anhydride (s).....	836.1
$C_7H_{10}O_3$	Terebic acid ( $\gamma$ , $\gamma$ -dimethylparaconic acid) (s).....	778.8
$C_7H_{12}O_7$	Glucosheptonic acid lactone (s).....	726.8
$C_8H_8O_3$	Phthalic anhydride (s).....	781.5
$C_8H_8O_3$	Phthalide (s).....	884
$C_8H_{10}O_3$	<i>cis</i> -Hexahydrophthalic anhydride (sol.) (s).....	932.0
	<i>trans</i> -Hexahydrophthalic anhydride (sol.) (s).....	937.8
$C_8H_{12}O_3$	<i>sym.</i> - <i>dl</i> -Diethylsuccinic anhydride (s).....	997.6
	<i>anti</i> -Diethylsuccinic anhydride (s).....	997.3
$C_8H_{12}O_3$	Diethylsuccinic anhydride ( <i>unsym.</i> ) (s).....	998
$C_8H_{12}O_3$	Tetramethylsuccinic anhydride (s).....	993
$C_8H_{14}O_3$	Glucosoctonic lactone (s).....	836.7
$C_{10}H_{16}O_3$	Phenylsuccinic anhydride (s).....	1094
$C_{10}H_{16}O_3$	Meconine (dimethoxyphthalide).....	1137
$C_{10}H_{16}O_3$	Camphoric anhydride (s).....	1252
$C_{10}H_{16}O_3$	Triethylsuccinic anhydride (s).....	1310
$C_{11}H_{18}O_3$	4-Methyl opianate (s).....	1263
$C_{12}H_{16}O_3$	Naphthalic anhydride (s).....	1258
$C_{12}H_{20}O_3$	Tetraethylsuccinic anhydride (s).....	1621
$C_{12}H_{22}O_3$	Diethylacetic anhydride (s).....	1669
$C_{14}H_{18}O_3$	Benzoic anhydride (s).....	1555
$C_{14}H_{20}O_3$	Heptylic anhydride (s).....	1985
$C_{16}H_{18}O_3$	Diphenylmaleic anhydride.....	1769
$C_{16}H_{18}O_3$	<i>dl</i> -Diphenylsuccinic anhydride (s).....	1816
$C_{16}H_{18}O_3$	Cinnamic anhydride (s).....	2091
$C_{16}H_{22}O_3$	Diphenylacetic anhydride (s).....	3308
$C_{17}H_{20}O_3$	Dibenzylacetic anhydride (glassy) (s).....	3931

## 5. C, H, O, CARBOHYDRATES: CELLULOSE, STARCH, ETC.

$C_5H_{10}O_5$	Arabinose (s).....	559
$C_5H_{10}O_5$	Xylose (s).....	561
$C_5H_{10}O_5$	<i>l</i> -Glucosan (s).....	678
$C_5H_{12}O_5$	Fucose (s).....	712
$C_5H_{12}O_5$	Rhamnose (s).....	718
$C_5H_{12}O_5$	Rhamnose (s).....	711.8
$C_5H_{12}O_5$	Galactose (s).....	670
$C_5H_{12}O_5$	<i>d</i> -Glucose (dextrose).....	673
$C_5H_{12}O_5$	<i>l</i> -Fructose (s).....	675
$C_5H_{12}O_5$	Sorbinose ( <i>d</i> -sorbose) (s).....	668
$C_7H_{14}O_7$	Glucosheptonic (s).....	783.8
$C_{12}H_{22}O_{11}$	Rhamnose triacetate (s).....	1351
$C_{12}H_{22}O_{11}$	Cellobiose (anhydr.) (s).....	1350
$C_{12}H_{22}O_{11}$	Lactose (anhydr.) (s).....	1350.8
$C_{12}H_{22}O_{11}.H_2O$	Lactose (s).....	1344.7
$C_{12}H_{22}O_{11}$	Maltose (s).....	1350.8
$C_{12}H_{22}O_{11}.H_2O$	Maltose (cryst.).....	1339.8
$C_{12}H_{22}O_{11}$	Sucrose (s)*.....	1349.8
$C_{12}H_{22}O_{11}$	Trehalose (cryst.).....	1341.8
$C_{12}H_{22}O_{11}$	Trehalose (mycose) (s).....	1349.4
$C_{14}H_{26}O_{11}$	Galactose pentaacetate (s).....	1726
$C_{14}H_{26}O_{11}$	Glucose pentaacetate (s).....	1726
$C_{15}H_{27}O_{14}.H_2O$	Melissitose (s).....	2042

\* s. p. 162.



Formula	Name	kg-cal <sub>15</sub> per mole
C <sub>12</sub> H <sub>22</sub> O <sub>11</sub>	Raffinose (melitose) (s)	2025.5
C <sub>12</sub> H <sub>22</sub> O <sub>11</sub> ·5H <sub>2</sub> O	Raffinose (cryst.)	2018.9
C <sub>12</sub> H <sub>22</sub> O <sub>11</sub>	Stachyose (anhyd.) (calc.) (s)	2709
C <sub>24</sub> H <sub>44</sub> O <sub>14</sub>	Cellobiose octoacetate (s)	3032.6
C <sub>24</sub> H <sub>44</sub> O <sub>14</sub>	Lactose octoacetate (s)	3029.3
C <sub>24</sub> H <sub>44</sub> O <sub>14</sub>	Maltose octoacetate (s)	3030.6
C <sub>24</sub> H <sub>44</sub> O <sub>14</sub>	Sucrose octoacetate (s)	3033.3

Name	g-cal <sub>15</sub> per gram
Starch	4179
Starch acetate	4499
Inulin	4130
	4190
Inulin acetate	4522
Dextrin	4110
Glycogen	4186.8
Cellulose	4181
Cellulose acetate	4496
Xylan	4260
Xylan acetate	4548

## 6. OTHER C, H, O-COMPOUNDS (partial list only; for complete list, v. (1))

Formula	Name	kg-cal <sub>15</sub> per mole
CH <sub>2</sub> O	Formaldehyde (g)	134
1/n (CH <sub>2</sub> O) <sub>n</sub>	Paraformaldehyde (s)	122
C <sub>2</sub> H <sub>4</sub> O	Acetaldehyde (g)	280.5
	(liquid)	279.0
C <sub>3</sub> H <sub>6</sub> O <sub>2</sub>	Methyl formate (g)	240.2
	(liquid)	233.1
C <sub>4</sub> H <sub>10</sub> O	Dimethyl ether (g)	347.6
C <sub>3</sub> H <sub>8</sub> O	Acetone	427
C <sub>3</sub> H <sub>8</sub> O <sub>2</sub>	Ethyl formate (g)	398.4
	(liquid)	391.7
C <sub>3</sub> H <sub>8</sub> O <sub>2</sub>	Methyl acetate (g)	397.7
	(liquid)	381.2
C <sub>3</sub> H <sub>8</sub> O	Methyl ethyl ether (g)	503.4
C <sub>3</sub> H <sub>8</sub> O <sub>2</sub>	Methylal	462.8
C <sub>4</sub> H <sub>10</sub> O	Methyl ethyl ketone	582
C <sub>4</sub> H <sub>10</sub> O <sub>2</sub>	Ethyl acetate (g)	544.4
	(liquid)	538.5
C <sub>4</sub> H <sub>10</sub> O <sub>2</sub>	Methyl propionate (g)	552.3
C <sub>4</sub> H <sub>10</sub> O	Diethyl ether (g)	660.3
	(liquid)	651.7
C <sub>4</sub> H <sub>10</sub> O	Diethyl ketone	736
C <sub>4</sub> H <sub>10</sub> O	Methyl propyl ketone	736
C <sub>4</sub> H <sub>10</sub> O	Methyl isopropyl ketone	734
C <sub>4</sub> H <sub>10</sub> O <sub>2</sub>	Ethyl propionate	690.8
C <sub>6</sub> H <sub>6</sub> O	Quinone (s)	656.5
C <sub>6</sub> H <sub>6</sub> O	Phenol (s)	732
C <sub>6</sub> H <sub>6</sub> O <sub>2</sub>	Pyrocatechol (s)	685
C <sub>6</sub> H <sub>6</sub> O <sub>2</sub>	Resorcinol (s)	683
C <sub>6</sub> H <sub>6</sub> O <sub>2</sub>	Hydroquinol (s)	683
C <sub>6</sub> H <sub>6</sub> O <sub>2</sub>	Pyrogallol (s)	639
C <sub>6</sub> H <sub>10</sub> O <sub>2</sub>	Ethyl acetoacetate	753.6
C <sub>6</sub> H <sub>10</sub> O <sub>2</sub>	Ethyl n-butyrate	851.2
C <sub>6</sub> H <sub>10</sub> O <sub>2</sub>	Ethyl isobutyrate	845.7
C <sub>7</sub> H <sub>14</sub> O	Dipropyl ketone	1051
C <sub>7</sub> H <sub>14</sub> O <sub>2</sub>	Amyl acetate	1040
C <sub>7</sub> H <sub>14</sub> O <sub>2</sub>	Ethyl valerate	1017
C <sub>8</sub> H <sub>10</sub> O	Acetophenone (s)	989
C <sub>8</sub> H <sub>10</sub> O <sub>2</sub>	Methyl benzoate	943.8
C <sub>8</sub> H <sub>10</sub> O <sub>2</sub>	Methyl salicylate	898.8
C <sub>8</sub> H <sub>16</sub> O	Methyl hexyl ketone	1205
C <sub>8</sub> H <sub>16</sub> O <sub>2</sub>	Ethyl benzoate	1099
C <sub>8</sub> H <sub>16</sub> O <sub>2</sub>	Ethyl p-hydroxybenzoate (s)	1043
C <sub>8</sub> H <sub>16</sub> O <sub>2</sub>	Ethyl salicylate	1051
C <sub>10</sub> H <sub>8</sub> O	α-Naphthol (s)	1185
C <sub>10</sub> H <sub>8</sub> O	β-Naphthol (s)	1187
C <sub>10</sub> H <sub>16</sub> O	Camphor (s)	1411
C <sub>11</sub> H <sub>16</sub> O	Benzophenone (s)	1557
C <sub>14</sub> H <sub>10</sub> O <sub>2</sub>	Anthraquinone (s)	1545

## 7. NITROGEN COMPOUNDS (partial list only; for complete list, v. (1))

CH <sub>3</sub> NO	Formamide	135
CH <sub>3</sub> NO <sub>2</sub>	Nitromethane	169.4
CH <sub>4</sub> N <sub>2</sub> O	Urea (s)	152
CH <sub>5</sub> N	Methylamine (g)	259
	(liquid)	256

Formula	Name	kg-cal <sub>15</sub> per mole
C <sub>2</sub> N <sub>2</sub>	Cyanogen (g)	260
C <sub>2</sub> H <sub>3</sub> N	Acetonitrile (g)	310.4
	(liquid)	302.4
C <sub>2</sub> H <sub>3</sub> NO	Glycolic nitrile	256.7
C <sub>2</sub> H <sub>3</sub> NO	Methyl isocyanate	269.4
C <sub>2</sub> H <sub>3</sub> NO <sub>2</sub>	Oxamic acid (s)	130
C <sub>2</sub> H <sub>4</sub> N <sub>2</sub> O <sub>2</sub>	Oxamide (s)	203
C <sub>2</sub> H <sub>5</sub> NO	Acetamide (s)	283
C <sub>2</sub> H <sub>5</sub> NO <sub>2</sub>	Nitroethane	322.2
C <sub>2</sub> H <sub>5</sub> NO <sub>2</sub>	Ethyl nitrite (g)	333
C <sub>2</sub> H <sub>5</sub> NO <sub>2</sub>	Glycine (aminoacetic acid) (s)	234
C <sub>2</sub> H <sub>5</sub> NO <sub>2</sub>	Ethyl nitrate (g)	322
C <sub>2</sub> H <sub>7</sub> N	Dimethylamine (g)	422
	(liquid)	417
C <sub>2</sub> H <sub>7</sub> N	Ethylamine (g)	413
	(liquid)	408.5
C <sub>2</sub> H <sub>8</sub> N <sub>2</sub> ·H <sub>2</sub> O	Ethylenediamine	452.6
C <sub>3</sub> H <sub>3</sub> N <sub>3</sub>	Malononitrile (s)	394.8
C <sub>3</sub> H <sub>3</sub> N <sub>2</sub> O <sub>3</sub>	Parabanic acid (s)	212.4
C <sub>3</sub> H <sub>4</sub> N <sub>2</sub> O <sub>2</sub>	Hydantoin (s)	311.7
C <sub>3</sub> H <sub>5</sub> N	Propionitrile	456.4
C <sub>3</sub> H <sub>5</sub> NO	Ethyl isocyanate	424.5
C <sub>3</sub> H <sub>5</sub> N <sub>2</sub> O <sub>2</sub>	Trinitroglycerol	432.4
C <sub>3</sub> H <sub>5</sub> N <sub>2</sub> O <sub>2</sub>	Malonamide (s)	359
C <sub>3</sub> H <sub>5</sub> N <sub>2</sub> O <sub>2</sub>	Hydantoic acid (s)	308.6
C <sub>3</sub> H <sub>7</sub> N	Allylamine (g)	528.1
	(liquid)	524.8
C <sub>3</sub> H <sub>7</sub> NO	Propionamide (s)	440
C <sub>3</sub> H <sub>7</sub> NO <sub>2</sub>	Alanine (s)	388.8
C <sub>3</sub> H <sub>7</sub> NO <sub>2</sub>	d-Alanine (s)	387.5
C <sub>3</sub> H <sub>7</sub> NO <sub>2</sub>	Nitropropane	477.9
C <sub>3</sub> H <sub>7</sub> NO <sub>2</sub>	Sarcosine (s)	401
C <sub>3</sub> H <sub>7</sub> NO <sub>2</sub>	Urethane (s)	397
C <sub>3</sub> H <sub>7</sub> NO <sub>2</sub>	Isoserine (s)	343.7
C <sub>3</sub> H <sub>5</sub> N <sub>2</sub> O	Ethylurea (s)	472
C <sub>3</sub> H <sub>5</sub> N	Propylamine (g)	572.3
	(liquid)	558.3
C <sub>3</sub> H <sub>5</sub> N	Trimethylamine	578.6
C <sub>4</sub> N <sub>2</sub>	Carbon subnitride (acetylenedicarboxylic acid nitrile) (s)	515
C <sub>4</sub> H <sub>2</sub> N <sub>2</sub> O <sub>4</sub> ·H <sub>2</sub> O	Alloxan (s)	276.3
C <sub>4</sub> H <sub>5</sub> N	Allyl cyanide	575
C <sub>4</sub> H <sub>5</sub> N	Trimethylene nitrile	581
C <sub>4</sub> H <sub>5</sub> N	Pyrrole	567.7
C <sub>4</sub> H <sub>5</sub> NO <sub>2</sub>	Succinimide (s)	438
C <sub>4</sub> H <sub>5</sub> N <sub>2</sub> O <sub>2</sub>	Diketopiperazine (s)	474.6
C <sub>4</sub> H <sub>7</sub> N	n-Butyronitrile	613.3
C <sub>4</sub> H <sub>7</sub> NO <sub>4</sub>	Aspartic acid (s)	384.9
C <sub>4</sub> H <sub>7</sub> N <sub>2</sub> O	Creatinine (s)	563.4
C <sub>4</sub> H <sub>5</sub> N <sub>2</sub> O <sub>2</sub>	Succinamide (s)	509.2
C <sub>4</sub> H <sub>5</sub> N <sub>2</sub> O <sub>2</sub>	Asparagine (s)	463.3
C <sub>4</sub> H <sub>5</sub> N <sub>2</sub> O <sub>2</sub> ·H <sub>2</sub> O	Asparagine (cryst.)	459.7
C <sub>4</sub> H <sub>7</sub> NO	n-Butylamide (s)	596.0
C <sub>4</sub> H <sub>7</sub> NO	Isobutylamide (s)	596.0
C <sub>4</sub> H <sub>7</sub> NO <sub>2</sub>	Isobutyl nitrite (g)	644.6
C <sub>4</sub> H <sub>7</sub> N <sub>2</sub> O <sub>2</sub>	Creatine (anhydr.) (s)	558
C <sub>4</sub> H <sub>7</sub> N <sub>2</sub> O <sub>2</sub> ·H <sub>2</sub> O	Creatine (cryst.)	553.1
C <sub>4</sub> H <sub>11</sub> N	n-Butylamine	710.6
C <sub>4</sub> H <sub>11</sub> N	Isobutylamine	713.6
C <sub>4</sub> H <sub>11</sub> N	sec-Butylamine	713
C <sub>4</sub> H <sub>11</sub> N	tert-Butylamine	716
C <sub>4</sub> H <sub>11</sub> N	Diethylamine (g)	731
	(liquid)	722.8
C <sub>4</sub> H <sub>9</sub> N <sub>4</sub> O <sub>2</sub>	Uric acid (s)	460.2
C <sub>5</sub> H <sub>5</sub> N	Pyridine	660
C <sub>5</sub> H <sub>5</sub> N <sub>2</sub> O	Guanine (s)	586
C <sub>5</sub> H <sub>5</sub> N <sub>2</sub> O <sub>2</sub>	4-Methyluracil (s)	566
C <sub>5</sub> H <sub>5</sub> N <sub>2</sub> O <sub>2</sub>	5-Methyluracil (s)	565
C <sub>5</sub> H <sub>5</sub> N <sub>4</sub> O <sub>4</sub>	Pseudouric acid (s)	454.2
C <sub>5</sub> H <sub>5</sub> N <sub>2</sub> O <sub>2</sub>	4-Methylhydrouacil (s)	618
C <sub>5</sub> H <sub>7</sub> NO <sub>4</sub>	Glutamic acid (act.) (s)	542.4
C <sub>5</sub> H <sub>11</sub> N	Piperidine	826.6
C <sub>5</sub> H <sub>11</sub> NO <sub>2</sub>	d,l-α-Aminoisovaleric acid (s)	701
C <sub>5</sub> H <sub>11</sub> N	Isoamylamine	867
C <sub>5</sub> H <sub>7</sub> N <sub>2</sub> O <sub>2</sub>	1, 2, 4-Trinitrobenzene (s)	674
C <sub>5</sub> H <sub>7</sub> N <sub>2</sub> O <sub>2</sub>	1, 3, 5-Trinitrobenzene (s)	664
C <sub>5</sub> H <sub>7</sub> N <sub>2</sub> O <sub>7</sub>	2, 4, 6-Trinitrophenol (s)	620
C <sub>6</sub> H <sub>4</sub> N <sub>2</sub> O <sub>4</sub>	o-Dinitrobenzene (s)	703.2



Formula	Name	kg-cal <sub>15</sub> per mole
7. NITROGEN COMPOUNDS.—(Continued)		
C <sub>6</sub> H <sub>4</sub> N <sub>2</sub> O <sub>4</sub>	<i>m</i> -Dinitrobenzene (s)	697
C <sub>6</sub> H <sub>4</sub> N <sub>2</sub> O <sub>4</sub>	<i>p</i> -Dinitrobenzene (s)	695
C <sub>6</sub> H <sub>4</sub> N <sub>2</sub> O <sub>4</sub>	2, 4-Dinitrophenol (s)	648
C <sub>6</sub> H <sub>5</sub> NO <sub>2</sub>	Nitrobenzene	739
C <sub>6</sub> H <sub>5</sub> NO <sub>2</sub>	<i>o</i> -Nitrophenol (s)	689
C <sub>6</sub> H <sub>5</sub> NO <sub>2</sub>	<i>m</i> -Nitrophenol (s)	684
C <sub>6</sub> H <sub>5</sub> NO <sub>2</sub>	<i>p</i> -Nitrophenol (s)	686
C <sub>6</sub> H <sub>5</sub> N <sub>2</sub> O <sub>2</sub>	<i>o</i> -Nitroaniline (s)	766
C <sub>6</sub> H <sub>5</sub> N <sub>2</sub> O <sub>2</sub>	<i>m</i> -Nitroaniline (s)	765
C <sub>6</sub> H <sub>5</sub> N <sub>2</sub> O <sub>2</sub>	<i>p</i> -Nitroaniline (s)	761
C <sub>6</sub> H <sub>5</sub> N <sub>2</sub> O <sub>3</sub>	<i>m</i> -Nitrophenylhydroxylamine	766
C <sub>6</sub> H <sub>7</sub> N	Aniline	812
C <sub>6</sub> H <sub>7</sub> N	$\alpha$ -Picoline	815
C <sub>6</sub> H <sub>7</sub> N	$\beta$ -Picoline	812
C <sub>6</sub> H <sub>7</sub> N	$\gamma$ -Picoline	816
C <sub>6</sub> H <sub>7</sub> NO	Phenylhydroxylamine	804
C <sub>6</sub> H <sub>8</sub> N <sub>2</sub>	Phenylhydrazine (s)	875
C <sub>6</sub> H <sub>8</sub> N <sub>2</sub>	<i>p</i> -Phenylenediamine (s)	805
C <sub>6</sub> H <sub>12</sub> N <sub>2</sub> O <sub>3</sub>	<i>d</i> -Alanine anhydride (s)	843
C <sub>6</sub> H <sub>12</sub> N <sub>4</sub>	Hexamethylenetetramine (s)	786
C <sub>6</sub> H <sub>13</sub> NO <sub>2</sub>	Leucine (s)	1006.7
C <sub>6</sub> H <sub>13</sub> N	Hexylamine	856
C <sub>6</sub> H <sub>13</sub> N	Triethylamine	1022
C <sub>7</sub> H <sub>5</sub> N	Benzonitrile	1037
C <sub>7</sub> H <sub>5</sub> NO <sub>2</sub>	<i>m</i> -Nitrobenzaldehyde (s)	866
C <sub>7</sub> H <sub>5</sub> NO <sub>4</sub>	<i>o</i> -Nitrobenzoic acid (s)	800
C <sub>7</sub> H <sub>5</sub> NO <sub>4</sub>	<i>m</i> -Nitrobenzoic acid (s)	735
C <sub>7</sub> H <sub>5</sub> NO <sub>4</sub>	<i>p</i> -Nitrobenzoic acid (s)	729
C <sub>7</sub> H <sub>5</sub> N <sub>3</sub> O <sub>6</sub>	2, 3, 4-Trinitrotoluene	728
C <sub>7</sub> H <sub>5</sub> N <sub>3</sub> O <sub>6</sub>	2, 3, 5-Trinitrotoluene (s)	833
C <sub>7</sub> H <sub>5</sub> N <sub>3</sub> O <sub>6</sub>	2, 3, 5-Trinitrotoluene	824
C <sub>7</sub> H <sub>5</sub> N <sub>3</sub> O <sub>6</sub>	2, 4, 6-Trinitrotoluene (s)	825
C <sub>7</sub> H <sub>5</sub> N <sub>3</sub> O <sub>6</sub>	3, 4, 5-Trinitrotoluene (s)	821
C <sub>7</sub> H <sub>5</sub> N <sub>3</sub> O <sub>6</sub>	3, 4, 6-Trinitrotoluene (s)	828
C <sub>7</sub> H <sub>5</sub> N <sub>3</sub> O <sub>6</sub>	3, 4, 6-Trinitrotoluene (s)	826
C <sub>7</sub> H <sub>5</sub> N <sub>3</sub> O <sub>6</sub>	Tetryl (s)	842
C <sub>7</sub> H <sub>5</sub> N <sub>3</sub> O <sub>6</sub>	2, 3-Dinitrotoluene (s)	842
C <sub>7</sub> H <sub>5</sub> N <sub>3</sub> O <sub>6</sub>	2, 4-Dinitrotoluene (s)	859
C <sub>7</sub> H <sub>5</sub> N <sub>3</sub> O <sub>6</sub>	2, 5-Dinitrotoluene (s)	853
C <sub>7</sub> H <sub>5</sub> N <sub>3</sub> O <sub>6</sub>	2, 6-Dinitrotoluene (s)	855
C <sub>7</sub> H <sub>5</sub> N <sub>3</sub> O <sub>6</sub>	3, 4-Dinitrotoluene (s)	854
C <sub>7</sub> H <sub>5</sub> N <sub>3</sub> O <sub>6</sub>	3, 5-Dinitrotoluene (s)	860
C <sub>7</sub> H <sub>7</sub> NO	Benzamide (s)	853
C <sub>7</sub> H <sub>7</sub> NO	Formanilide (s)	848
C <sub>7</sub> H <sub>7</sub> NO <sub>2</sub>	<i>o</i> -Nitrotoluene	861
C <sub>7</sub> H <sub>7</sub> NO <sub>2</sub>	<i>m</i> -Nitrotoluene	897
C <sub>7</sub> H <sub>7</sub> NO <sub>2</sub>	<i>p</i> -Nitrotoluene (s)	893
C <sub>7</sub> H <sub>7</sub> N <sub>3</sub> O <sub>4</sub>	2, 4-Dinitromethylaniline (s)	889
C <sub>7</sub> H <sub>7</sub> N <sub>3</sub> O <sub>4</sub>	<i>p</i> -Nitromethylaniline (s)	884.5
C <sub>7</sub> H <sub>7</sub> N <sub>3</sub> O <sub>4</sub>	Theobromine (s)	924
C <sub>7</sub> H <sub>7</sub> N	Benzylamine	845
C <sub>7</sub> H <sub>7</sub> N	Methylaniline	967
C <sub>7</sub> H <sub>7</sub> N	<i>o</i> -Toluidine	973.5
C <sub>7</sub> H <sub>7</sub> N	<i>m</i> -Toluidine	964
C <sub>7</sub> H <sub>7</sub> N	<i>p</i> -Toluidine	965
C <sub>7</sub> H <sub>17</sub> N	Heptylamine	958
C <sub>8</sub> H <sub>5</sub> NO	Benzoyl cyanide (s)	1179
C <sub>8</sub> H <sub>5</sub> NO <sub>2</sub>	Isatin (s)	940
C <sub>8</sub> H <sub>5</sub> NO <sub>2</sub>	Phthalimide (s)	868
C <sub>8</sub> H <sub>7</sub> N	Benzyl cyanide	850
C <sub>8</sub> H <sub>7</sub> N	Indole (s)	1024
C <sub>8</sub> H <sub>7</sub> NO <sub>2</sub>	Dioxindol (s)	1022
C <sub>8</sub> H <sub>7</sub> N <sub>3</sub> O <sub>4</sub>	Methyltetryl (s)	916
C <sub>8</sub> H <sub>7</sub> N <sub>3</sub> O <sub>4</sub>	<i>o</i> -Nitroacetanilide (s)	1009
C <sub>8</sub> H <sub>7</sub> N <sub>3</sub> O <sub>4</sub>	<i>m</i> -Nitroacetanilide (s)	974
C <sub>8</sub> H <sub>7</sub> N <sub>3</sub> O <sub>4</sub>	<i>p</i> -Nitroacetanilide (s)	970
C <sub>8</sub> H <sub>9</sub> NO	Acetanilide (s)	968
C <sub>8</sub> H <sub>9</sub> NO <sub>2</sub>	Phenylglycine (phenylaminoacetic acid) (s)	1010
C <sub>8</sub> H <sub>9</sub> NO <sub>2</sub>	<i>o</i> -Nitrophenetole	955
C <sub>8</sub> H <sub>9</sub> NO <sub>2</sub>	<i>m</i> -Nitrophenetole	1021
C <sub>8</sub> H <sub>9</sub> NO <sub>2</sub>	<i>p</i> -Nitrophenetole	1009
C <sub>8</sub> H <sub>10</sub> N <sub>2</sub> O <sub>2</sub>	Caffeine (s)	1006
C <sub>8</sub> H <sub>11</sub> N	Dimethylaniline	1014
C <sub>8</sub> H <sub>11</sub> N	Ethylaniline	1148
C <sub>8</sub> H <sub>13</sub> N <sub>2</sub> O	Veronal (5,5-diethylbarbituric acid) (s)	1122
C <sub>8</sub> H <sub>17</sub> N	Coniine	983
C <sub>8</sub> H <sub>19</sub> N	Diisobutylamine	1275
C <sub>8</sub> H <sub>7</sub> N	Quinoline	1348

Formula	Name	kg-cal <sub>15</sub> per mole
C <sub>8</sub> H <sub>9</sub> N	3-Methylindole	1176
C <sub>8</sub> H <sub>9</sub> N	$\alpha$ -Methylindole	1169
C <sub>8</sub> H <sub>9</sub> NO <sub>2</sub>	Hippuric acid (s)	1012
C <sub>8</sub> H <sub>11</sub> NO	Propionanilide (s)	1168
C <sub>8</sub> H <sub>11</sub> NO <sub>2</sub>	Phenylalanine (s)	1111
C <sub>8</sub> H <sub>11</sub> NO <sub>2</sub>	Tyrosine (s)	1070
C <sub>8</sub> H <sub>13</sub> N	Benzylethylamine	1290
C <sub>10</sub> H <sub>9</sub> N	$\alpha$ -Naphthylamine (s)	1264
C <sub>10</sub> H <sub>9</sub> N	$\beta$ -Naphthylamine (s)	1261
C <sub>10</sub> H <sub>9</sub> NO <sub>4</sub>	Hemipinimide (s)	1099
C <sub>10</sub> H <sub>13</sub> N	Tetrahydroquinoline	1382
C <sub>10</sub> H <sub>13</sub> NO <sub>2</sub>	Phenacetin (s)	1285
C <sub>10</sub> H <sub>14</sub> N <sub>2</sub>	Nicotine	1428
C <sub>10</sub> H <sub>15</sub> N	Diethylaniline	1452
C <sub>10</sub> H <sub>23</sub> N	Diisobutylamine	1660
C <sub>11</sub> H <sub>7</sub> N	$\alpha$ -Naphthonitrile (s)	1326
C <sub>11</sub> H <sub>7</sub> N	$\beta$ -Naphthonitrile (s)	1321
C <sub>12</sub> H <sub>9</sub> N	Carbazole (s)	1475
C <sub>12</sub> H <sub>10</sub> N <sub>2</sub>	Azobenzene (s)	1546
C <sub>12</sub> H <sub>11</sub> N	Diphenylamine (s)	1538
C <sub>12</sub> H <sub>12</sub> N <sub>2</sub>	Hydrazobenzene (s)	1597
C <sub>12</sub> H <sub>12</sub> N <sub>2</sub>	Benzidine (s)	1599
C <sub>12</sub> H <sub>27</sub> N	Triisobutylamine	1561
C <sub>13</sub> H <sub>11</sub> NO	Benzanilide (s)	1974
C <sub>13</sub> H <sub>12</sub> N <sub>2</sub> O	<i>sym</i> -Diphenylurea (s)	1576
C <sub>13</sub> H <sub>12</sub> N <sub>2</sub> O	<i>unsym</i> -Diphenylurea (s)	1612
C <sub>14</sub> H <sub>15</sub> N	Dibenzylamine (s)	1614
C <sub>15</sub> H <sub>23</sub> N	Triisobutylamine	1853
C <sub>16</sub> H <sub>10</sub> N <sub>2</sub> O <sub>2</sub>	Indigo (s)	2459
C <sub>16</sub> H <sub>13</sub> N	Phenyl- $\alpha$ -naphthylamine (s)	1815
C <sub>16</sub> H <sub>13</sub> N	Phenyl- $\beta$ -naphthylamine (s)	2004
C <sub>17</sub> H <sub>19</sub> NO <sub>3</sub> ·H <sub>2</sub> O	Morphine (s)	1998
C <sub>18</sub> H <sub>15</sub> N	Triphenylamine (s)	2146
C <sub>18</sub> H <sub>21</sub> NO <sub>3</sub> ·H <sub>2</sub> O	Codeine (s)	2268
C <sub>19</sub> H <sub>21</sub> NO <sub>3</sub>	Thebaine (s)	2328
C <sub>20</sub> H <sub>21</sub> NO <sub>4</sub>	Papaverine (s)	2441
C <sub>20</sub> H <sub>27</sub> NO <sub>11</sub>	Amygdalin (s)	2478
C <sub>21</sub> H <sub>21</sub> N	Tribenzylamine (s)	2348
C <sub>21</sub> H <sub>23</sub> N <sub>2</sub> O <sub>2</sub>	Strychnine (s)	2762
C <sub>22</sub> H <sub>23</sub> NO <sub>7</sub>	Narcotine (s)	2686
C <sub>23</sub> H <sub>25</sub> N <sub>2</sub> O <sub>4</sub>	Brucine (s)	1644
C <sub>23</sub> H <sub>27</sub> NO <sub>8</sub> ·2H <sub>2</sub> O	Narceine (s)	2933

8. HALOGEN COMPOUNDS (partial list only; for complete list, *v.* (1)). Final states: dil. solution of HCl; Br vapor; solid I<sub>2</sub>

CCl <sub>4</sub>	Carbon tetrachloride (g)	44.5
	(liquid)	37.3
CHCl <sub>3</sub>	Chloroform (g)	70.3
	(liquid)	89.2
CHI <sub>3</sub>	Iodoform (s)	162
CH <sub>2</sub> Cl <sub>2</sub>	Methylene chloride (g)	106.8*
CH <sub>2</sub> I <sub>2</sub>	Methylene iodide	178
CH <sub>3</sub> Br	Methyl bromide (g)	184
		180
CH <sub>3</sub> Cl	Methyl chloride	164
		173
CH <sub>3</sub> I	Methyl iodide (g)	200.5
	(liquid)	194.7
C <sub>2</sub> HCl <sub>3</sub> O <sub>2</sub>	Trichloroacetic acid (s)	92.8
C <sub>2</sub> H <sub>3</sub> ClO	Chloroacetaldehyde	234.4
C <sub>2</sub> H <sub>3</sub> ClO <sub>2</sub>	Chloroacetic acid (s)	171.0
C <sub>2</sub> H <sub>4</sub> Cl <sub>2</sub>	Ethylene chloride (g)	271.0
C <sub>2</sub> H <sub>4</sub> Cl <sub>2</sub>	Ethylidene chloride (g)	271.1
	(liquid)	267.1*
C <sub>2</sub> H <sub>5</sub> Br	Ethyl bromide (g)	340
		329
C <sub>2</sub> H <sub>5</sub> Cl	Ethyl chloride (g)	316.7
		326.9
C <sub>2</sub> H <sub>5</sub> I	Ethyl iodide (g)	358
	(liquid)	356
C <sub>3</sub> H <sub>5</sub> Cl	Allyl chloride (g)	440.8
C <sub>3</sub> H <sub>7</sub> Br	Propyl bromide (g)	497
C <sub>3</sub> H <sub>7</sub> Cl	Propyl chloride (g)	478.3
C <sub>3</sub> H <sub>7</sub> I	<i>n</i> -Propyl iodide	514.3
C <sub>3</sub> H <sub>7</sub> I	Isopropyl iodide	509.1
C <sub>4</sub> H <sub>6</sub> Cl <sub>2</sub> O <sub>2</sub>	Ethyl dichloroacetate	463.4

\* HCl gas.



Formula	Name	kg-cal <sub>18</sub> per mole
C <sub>4</sub> H <sub>7</sub> ClO <sub>2</sub>	Ethyl chloroacetate.....	493.9
C <sub>4</sub> H <sub>9</sub> Cl	Isobutyl chloride.....	635.5
C <sub>6</sub> Cl <sub>4</sub> O <sub>2</sub>	Tetrachloroquinone (s).....	517.7
C <sub>6</sub> HCl <sub>3</sub> O <sub>2</sub>	Trichloroquinone (s).....	546.4
C <sub>6</sub> H <sub>2</sub> Cl <sub>2</sub> O <sub>2</sub>	2, 6-Dichloroquinone (s).....	578.9
C <sub>6</sub> H <sub>2</sub> Cl <sub>3</sub> O <sub>2</sub>	Chloroanilic acid (s).....	484.9
C <sub>6</sub> H <sub>2</sub> Cl <sub>4</sub> O <sub>2</sub>	Tetrachlorohydroquinol (s).....	563
C <sub>6</sub> H <sub>2</sub> ClO <sub>2</sub>	Chloroquinone (s).....	616.6
C <sub>6</sub> H <sub>2</sub> Cl <sub>3</sub> O <sub>2</sub>	Trichlorohydroquinol (s).....	593
C <sub>6</sub> H <sub>4</sub> Cl <sub>2</sub>	o-Dichlorobenzene (s).....	671.8
C <sub>6</sub> H <sub>4</sub> Cl <sub>2</sub> O <sub>2</sub>	2, 6-Dichlorohydroquinol (s).....	614
C <sub>6</sub> H <sub>4</sub> ClO <sub>2</sub>	Chlorohydroquinol (s).....	646
C <sub>6</sub> H <sub>5</sub> I	Phenyl iodide.....	771
C <sub>7</sub> H <sub>5</sub> ClO	Benzoyl chloride.....	783
C <sub>7</sub> H <sub>7</sub> Cl	Benzyl chloride.....	886.4
C <sub>8</sub> H <sub>5</sub> Cl <sub>2</sub> O <sub>2</sub>	Phthalyl chloride (s).....	802

9. SULFUR COMPOUNDS, final state: dilute H<sub>2</sub>SO<sub>4</sub> aq., except as otherwise noted

COS	Carbonyl sulfide (g).....	130.5*
CS <sub>2</sub>	Carbon disulfide.....	246.6*
CH <sub>3</sub> N <sub>2</sub> S	Thiourea (s).....	342.8†
CH <sub>3</sub> S	Methylmercaptan (g).....	297.6*
C <sub>2</sub> H <sub>5</sub> NS	Methyl thiocyanate (g).....	397.4*
	(liquid).....	453.1
C <sub>2</sub> H <sub>5</sub> NS	Methyl isothiocyanate (g).....	390.5*
	(s).....	442.9
C <sub>2</sub> H <sub>6</sub> S	Dimethyl sulfide (g).....	455.6*
C <sub>2</sub> H <sub>6</sub> S	Ethylmercaptan (g).....	452.0*
	(liquid).....	517.2
C <sub>2</sub> H <sub>7</sub> NO <sub>2</sub> S	Taurine (s).....	382.9
C <sub>2</sub> H <sub>7</sub> N <sub>2</sub> OS	Thiohydantoin (s).....	503.0
C <sub>2</sub> H <sub>7</sub> NS	Ethyl thiocyanate.....	613.8

Formula	Name	kg-cal <sub>18</sub> per mole
C <sub>2</sub> H <sub>5</sub> NS	Ethyl isothiocyanate.....	604.1
C <sub>2</sub> H <sub>5</sub> N <sub>2</sub> O <sub>2</sub> S	Thiohydantoic acid (s).....	498.5
C <sub>6</sub> H <sub>4</sub> S	Thiophene (liquid).....	670.5
	(g).....	608.2
C <sub>6</sub> H <sub>5</sub> NS	Allyl mustard oil (liquid).....	733
	(g).....	673*
C <sub>4</sub> H <sub>8</sub> N <sub>2</sub> S	Allythiourea (s).....	792
C <sub>4</sub> H <sub>8</sub> NS <sub>2</sub>	Dimethyl N-methylcarbimidedithiolate.....	969
C <sub>4</sub> H <sub>8</sub> NS <sub>2</sub>	S-Methyl N-dimethyldithiocarbamate (sol.).....	954
C <sub>4</sub> H <sub>8</sub> NS <sub>2</sub>	Methyl formothialdine.....	964.5
C <sub>4</sub> H <sub>10</sub> S	Diethyl sulfide (g).....	769*
	(liquid).....	829
C <sub>5</sub> H <sub>4</sub> O <sub>2</sub> S	α-Thiophenecarboxylic acid (s).....	646
C <sub>5</sub> H <sub>5</sub> O <sub>2</sub> S	Tetrahydro-α-thiophenecarboxylic acid (s).....	755
C <sub>5</sub> H <sub>10</sub> N <sub>2</sub> S <sub>2</sub>	Dimethyl formocarbthialdine (sol.).....	1098
C <sub>5</sub> H <sub>10</sub> N <sub>2</sub> S <sub>2</sub>	Carbthialdine (sol.).....	1086
C <sub>5</sub> H <sub>10</sub> N <sub>2</sub> S <sub>2</sub>	Pentamethylenediamine disulfine (sol.).....	1113
C <sub>5</sub> H <sub>11</sub> NS <sub>2</sub>	S-Ethyl N-dimethyldithiocarbamate.....	1122
C <sub>5</sub> H <sub>11</sub> NS <sub>2</sub>	Dimethyl N-ethylcarbimidedithiolate.....	1130
C <sub>6</sub> H <sub>12</sub> N <sub>2</sub> O <sub>4</sub> S <sub>2</sub>	Cystine (s).....	994*
C <sub>6</sub> H <sub>13</sub> NS <sub>2</sub>	S-Methyl N-diethyldithiocarbamate.....	1272
C <sub>6</sub> H <sub>13</sub> NS <sub>2</sub>	Diethyl N-methylcarbimidedithiolate.....	1289
C <sub>6</sub> H <sub>13</sub> NS <sub>2</sub>	Thialdine (sol.).....	1264
C <sub>7</sub> H <sub>5</sub> NS	Phenyl isothiocyanate.....	1024
C <sub>9</sub> H <sub>11</sub> NS <sub>2</sub>	Dimethyl N-phenylcarbimidedithiolate.....	1545
C <sub>15</sub> H <sub>14</sub> N <sub>2</sub> O <sub>2</sub> S	Benzonaphthoquinonethiazine (s).....	2278

\* Gaseous SO<sub>2</sub>.† H<sub>2</sub>SO<sub>4</sub>·200H<sub>2</sub>O.

## LITERATURE

(For a key to the periodicals see end of volume)

- (1) Kharasch, 546; 2: 359; 29. (2) Schläpfer and Fioroni, 37, 6: 713; 23.  
 (3) Swietoslawski, 42, 22: 583; 25. (4) Verkade and Coops, 70, 42: 205;  
 23. (5) Verkade and Coops, 7, 118: 123; 25.

## THERMOCHEMISTRY: HEATS OF FORMATION UNDER CONSTANT PRESSURE (HEATS OF SOLUTION. HEATS OF TRANSITION)

F. RUSSELL BICHOWSKY

## EXPLANATION

Arrangement.—Standard, v. Vol. III, p. viii.

Column 1. *Formula*.—The formula appearing in Column 1 identifies the substance whose heat of formation per g.f.w. (gram-formula-weight) is shown in Column 3. Polymorphic forms or states requiring further description than that given in Column 2 are indicated by arbitrary signs in parentheses; e.g., by Greek letters, Roman numerals, or descriptive phrases. The polymorphic forms are further identified by the transition temperature given in Column 4 as superscript after the abbreviation, Tr.

Column 2. *Physical State*.—For each substance the physical state to which the heat of formation refers is indicated in Column 2. See list of abbreviations below. All states are for 1 atm. and 18°C, unless otherwise indicated by superscript in Column 3. Numerals or formulae in Column 2 indicate that the substance is in solution, one g.f.w. being dissolved in X g.f.w. of the solvent. Where the solvent is not explicitly stated, water is to be understood. Where the solvent is given but the concentration not stated, the solution is "dilute." Thus, 200 = "1 g.f.w. of the substance (Column 2) dissolved in 200 × 18 g H<sub>2</sub>O;" 200C<sub>2</sub>H<sub>5</sub>OH = "1 g.f.w. of the substance dissolved in 200 × 46.0 g C<sub>2</sub>H<sub>5</sub>OH;" CS<sub>2</sub> = "1 g.f.w. of the substance dissolved in a large amount of CS<sub>2</sub>," etc.

Column 3. *Heat of Formation*.—The values in Column 3 are the number of kilojoules, kj (absolute), of heat evolved when one g.f.w. of the substance (shown in Column 1), in the state given in Column 2, is produced out of its elements, in their standard states, at 18° and 1 atm. According to the above definition the heat of formation of an element in its standard state is zero. The

standard state of any element may be located by this fact and by the abbreviation "Def." in Column 3 opposite the formula of the element. Heats of formation of ions are based on the arbitrary value, 0, for H<sup>+</sup>, and are for dilute solutions of completely ionized electrolytes.

*Accuracy*.—All the values recorded in this table have been recomputed from the original experimental data, using consistent values for all subsidiary quantities. Heats of reactions and of dilution may therefore be computed by difference with an accuracy as high as known. Estimated accuracy is indicated by number of significant figures. This accuracy is not the absolute accuracy, but the accuracy of the particular reaction used to compute the figure given (v. Column 4). The absolute accuracy will be less than that of the least accurate determination in the total chain of reactions used to calculate the heat of formation from the elements.

Column 4. *Method*.—In Column 4 an attempt has been made to indicate in a general way the reactions which have been employed in computing the values given. See list of abbreviations below. Formulae in this column, e.g., MOH, indicate that the heat of formation of M<sup>+</sup> depends on the value in the table for the heat of formation of dilute MOH solution. Numerals in this column, e.g., 3.65, not preceded by the abbreviation Tr., indicate the experimentally determined heat of solution, on which the value in Column 4 is based, e.g., 3.65 kj. Numerals in this column following the sign, Tr., e.g., Tr. 0.8, indicate the experimentally determined heat of transition, e.g., 0.8 kj. Superscripts indicate the temperature at which the reaction was measured.

Column 5. *Literature References*.—References are to the original publication, except in the case of Thomsen, where values



are usually quoted from his book. Where the method used by the author is non-calorimetric, *e.g.*, temperature coefficient of EMF, etc., the reference is starred. If the reference contains values determined at other temperatures, it is followed by the symbol, °. If it contains values for the partial heat of solution or other "partial" thermal quantities, the reference is followed by the symbol, †. By partial thermal quantities is meant  $\frac{\partial \Delta Q}{\partial N_1}$  where  $N_1$  is the concentration of the substance, 1, in any units, usually mole fractions.

### Computations

To compute the heat of any process involving the disappearance of a substance or substances in the states given in the table and the appearance of other or the same substances in states given in the table: Add together the heats of formation of the products of the process in the final states and subtract therefrom the sum of the heats of formation of the reactants in their initial states. Thus:

*Heat of Reaction.*— $\text{CaO (crys.)} + \text{H}_2\text{O (liq.)} = \text{Ca(OH)}_2 \text{ (crys.)}$ ,  $\Delta Q = Q_{\text{Ca(OH)}_2} - [Q_{\text{CaO}} + Q_{\text{H}_2\text{O}}] = 988 - [634.9 + 286.2] = 66.9 \text{ kJ}$ .

*Heat of Solution.*—If a direct experimental determination is available, it will be found in Column 3 in the form  $8.66_{400}^{18}$  which indicates that the heat of solution of one g.f.w. of the substance in 400 moles of  $\text{H}_2\text{O}$  at  $18^\circ$  is 8.66 kJ. When the temperature or dilution is not indicated, the precise value is not given in the original, and the value is for "room temperature" and for a "dilute" solution. If the heat of solution is not directly given in Column 4 it may be found by writing the reaction and proceeding as with heats of reaction above. For example, to find the heat of solution of  $\text{SrCl}_2 \cdot 2\text{H}_2\text{O}$  in 400 moles of water, write:  $\text{SrCl}_2 \cdot 2\text{H}_2\text{O} = \text{SrCl}_{2(400)} + 2\text{H}_2\text{O}$ ;  $\Delta Q = 874.7 + 2 \times 286.2 - 1438.4 = 8.7 \text{ kJ}$ .

*Heat of Dilution.*—The molal integral heat of dilution, *i.e.*, the heat of diluting, with  $y$  moles of  $\text{H}_2\text{O}$ , a solution of one g.f.w. of the substance in  $x$  moles of  $\text{H}_2\text{O}$  is the excess of the heat of formation of 1 g.f.w. of the substance in the final solution over its heat of formation in the initial solution. Thus: The heat of diluting one mole of  $\text{H}_2\text{SO}_4$  in 99 moles of water to one mole of  $\text{H}_2\text{SO}_4$  in 799 moles of water is  $871.6 - 867.8 = 3.8 \text{ kJ}$ .

*Heat of Transition.*—If both forms of the substance can be obtained at  $18^\circ$  and one atmosphere, subtract the heat of formation of the final form from that of the initial form. For transitions which can be realized under 1 atm. only at temperatures other than  $18^\circ$ , the heat of transition will be found in Column 3 after the abbreviation, Tr. For example, the heat of transition from  $\text{Mn}^\alpha$  to  $\text{Mn}^\beta$  is given in the form  $\text{Mn}_\alpha \dots \text{Tr.}; 5.5_{1100}^{18}$  which means that 5.5 kJ of heat is evolved when one gram-atomic-weight of  $\alpha$ -manganese changes to  $\beta$ -manganese at  $1100^\circ$ .

*Heats of Ionization.*—The heat of formation of a completely ionized solution of a substance can be considered as the sum of the heats of formation of its ions. Therefore, if the heat of formation of a completely ionized solution is known, and that of all but one of its ions is known the heat of formation of the other ion may be calculated. This method has been used in calculating the heats of formation of ions given in the table, the heat of formation of  $\text{H}^+$  being arbitrarily taken as zero. Conversely, knowing heats of formation of the ions, the heat of formation of a dilute solution of a strong electrolyte may be found by addition of the heats of formation of its ions; *e.g.*, the heat of formation of  $(\text{NH}_4)_2\text{SeO}_4 \text{ (aq.)} = 2Q_{\text{NH}_4^+} + Q_{\text{SeO}_4^{2-}} = 2 \times 132.7 + 613 = 878.4 \text{ kJ}$ . Similarly, the heat of ionization of a weak electrolyte may be computed by summing the heats of formation of its ions and subtracting therefrom its heat of formation; *e.g.*,  $\text{H}_2\text{O} = \text{OH}^- + \text{H}^+$ ;  $\Delta Q = Q_{\text{OH}^-} + Q_{\text{H}^+} - Q_{\text{H}_2\text{O}} = 228.2 + 0 - 286.2 = -58.0 \text{ kJ}$ .

## ABBREVIATIONS, SIGNS AND FORMS

### Abbreviations

amorp.	Amorphous, cryocrystalline or ill defined solid state.
aq.	Dilute aqueous solution.
c	Macrocrystalline.
coll.	Colloidal gel or sol.
Def.	Standard state.
dil.	Depends upon a heat of dilution.
dissoc.	Depends upon a heat of dissociation.
extrap.	Extrapolated.
gls.	A glass or solid supercooled liquid.
(ideal)	In the condition indicated by the formula; <i>e.g.</i> , for $\text{N}_2\text{O}_4$ the word "(ideal)" in Column 2 indicates that the heat of formation is for a gas composed of $\text{N}_2\text{O}_4$ molecules only.
liq.	Liquid.
mix.	Heat of mixing.
N	From heat of neutralization.
ppt.	Precipitated or from heat of precipitation.
sat.	In saturated solution in $\text{H}_2\text{O}$ .

### Signs

#### IN THE TABLE

*	By indirect non-calorimetric methods.
&	By several different methods.
$\infty$	In an infinite amount of $\text{H}_2\text{O}$ unless otherwise indicated.

#### IN THE LITERATURE REFERENCE COLUMN

*	By indirect non-calorimetric methods.
†	Includes determination or compilation of "partial" quantities.
°	Includes determinations at temperatures other than $18^\circ$ .

### Forms

+X <sub>1</sub>	Deduced from heat of reaction with X <sub>1</sub> .
Tr.; 0.92 <sub>(1)</sub> <sup>17</sup>	The heat of transition to crystalline form "I" is 0.92 kJ at $427^\circ$ .

### SUPERSCRIPTS

2(300) <sup>35</sup>	A superscript indicates the temperature.
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### SUBSCRIPTS

365 <sub>100</sub>	The dilution of the final solution is 100 moles of $\text{H}_2\text{O}$ per gram-formula-weight of substance.
365 <sub>1KOH</sub>	In a dilute KOH solution.
365 <sub>100KOH(100)</sub>	The solvent is one mole KOH to 100 moles $\text{H}_2\text{O}$ .
365 <sub>24KCN</sub>	The solvent is a solution containing 24 moles of KCN per mole solute.

### Illustrative Examples

$\text{H}_2\text{O}$ .—The information given in Columns 2 and 3 is equivalent to the following: "When two atomic weights (2.0154 g) of hydrogen gas ( $\text{H}_2$ ) at  $18^\circ$  and 1 atm. react with one atomic weight (16.00 g) of oxygen gas at  $18^\circ$  and 1 atm. to produce one g.f.w. (18.0154 g) of liquid  $\text{H}_2\text{O}$  at  $18^\circ$  and one atm., 286.2 kJ of heat are evolved." This is equivalent (*see* conversion factors given below) to  $0.23895 \times 286.2 = 68.39 \text{ kg-cal.}$  and to  $0.94823 \times 286.2 = 270.4 \text{ BTU}_{50}$ ; it is also equivalent to  $\frac{0.94823 \times 286.2}{18.0154} \times 453.59243 = 6831 \text{ BTU}_{50}$  per lb. of  $\text{H}_2\text{O}$  produced or to  $\frac{0.94823 \times 286.2}{16.0} \times 453.59243 = 7693 \text{ BTU}_{50}$  per lb.  $\text{O}_2$  consumed.

$\text{Cl}^-$ .—The information given in Columns 2, 3 and 4 is equivalent to the following: "The heat of formation of a completely ionized



solution containing one g.f.w. (35.458 g) of  $\text{Cl}^-$  and the equivalent amount of some positive ion (e.g., a solution of  $\text{Cl}^- + \text{H}^+ = \text{HCl}_{\infty}$ ) is the sum of the heat of formation of  $\text{Cl}^-$ ,  $Q = 165.55$ , and of  $\text{H}^+$ ,  $Q = 0$ , which is  $Q = 165.55 \text{ kJ}$ .

$\text{H}_2\text{O}_{2(200)}$ .—The information given in Columns 2 and 3 is equivalent to the following: "When two gram-atomic-weights ( $2 \times 1.0077 \text{ g}$ ) of hydrogen gas at  $18^\circ$  and 1 atm. react with two gram-atomic-weights ( $2 \times 16.00 \text{ g}$ ) of oxygen gas at  $18^\circ$  and 1 atm. and the product, 1 g.f.w. (34.0154 g) of  $\text{H}_2\text{O}_2$ , is dissolved in 200 g.f.w. of  $\text{H}_2\text{O}$  ( $18.0154 \times 200 = 3603.08 \text{ g}$ ), 188.2 kJ of heat is given out." The resulting solution contains 1 g.f.w. of  $\text{H}_2\text{O}_2$  in 200 g.f.w. of  $\text{H}_2\text{O}$ . The mole ratio of water in the solution is therefore 200, the mole ratio of  $\text{H}_2\text{O}_2$  is 0.005. The mole fraction of  $\text{H}_2\text{O}_2$  is  $\frac{1}{200 + 1} = 0.004925$ ; of  $\text{H}_2\text{O}$  is  $\frac{200}{200 + 1} = 0.995075$ .

The concentration in g.f.w.  $\text{H}_2\text{O}_2$  per 1000 g water is  $\frac{1000}{200 \times 18.0154} = 0.2775$ . The solution contains  $\frac{34.0154 \times 100}{(200 \times 18.0154) + 34.0154} = 0.935 \text{ Wt. \% of } \text{H}_2\text{O}_2$ .

### Explication

**Arrangement.**—Type, voir Vol. III, p. viii.

**Colonne 1. Formule.**—La formule présentée dans la colonne 1 identifie la substance dont la chaleur de formation par mol gr. (poids moléculaire en grammes) est indiqué dans la colonne 3. Les formes ou états polymorphiques nécessitant une description plus ample que celle donnée dans la colonne 2 sont indiqués par des signes arbitraires entre parenthèses, par exemple au moyen de lettres grecques, de chiffres romains ou de phrases descriptives. Les formes polymorphiques sont de plus identifiées dans la colonne 4 par la température de transition inscrites après l'abréviation Tr.

**Colonne 2. État physique.**—L'état physique auquel la chaleur de formation se rapporte est indiqué pour chaque substance dans la colonne 2. Voir la liste des abréviations ci-dessous. Tous les états sont considérés sous 1 atm. et à  $18^\circ\text{C}$ , à moins d'une annotation inscrite dans la colonne 3. Les chiffres et formules de la colonne 2 indiquent que la substance est en solution, une mol gr. étant dissoute dans  $X$  mol gr. du dissolvant. Dans le cas où le dissolvant n'est pas défini explicitement, il s'agit de l'eau. Lorsque le dissolvant est donné mais que la concentration n'est pas établie, la solution est "diluée." Ainsi  $200 = "1 \text{ mol gr. de la substance (colonne 2) dissoute dans } 200 \times 18 \text{ g } \text{H}_2\text{O};" 200\text{C}_2\text{H}_5\text{OH} = "1 \text{ mol gr. de la substance dissoute dans } 200 \times 46,0 \text{ g } \text{C}_2\text{H}_5\text{OH}; \text{CS}_2 = "1 \text{ mol gr. de la substance dissoute dans une grande quantité de } \text{CS}_2," \text{ etc.}$

**Colonne 3. Chaleur de formation.**—Les valeurs consignées dans la 3ème colonne sont le nombre de kilojoules, kJ (absolu) de chaleur dégagée lorsqu'une mol gr. de la substance (indiquée dans la colonne 1) sous l'état donné dans la colonne 2 est produite à partir de ses éléments sous leur état type, à  $18^\circ$  et 1 atm. Conformément à la définition donnée ci-dessus, la chaleur de formation d'un élément se trouvant dans son état type est égale à zéro. L'état type de chaque élément peut être fixé par ce fait et par l'abréviation "Def." dans la colonne 3, en regard de la formule de l'élément. Les chaleurs de formation des ions sont basées sur la valeur arbitraire, 0, pour  $\text{H}^+$  et sont pour les solutions diluées d'électrolytes complètement ionisés.

**Précision.**—Toutes les valeurs consignées dans ces tables ont été recalculées à partir des données expérimentales originales, en se servant de valeurs compatibles pour toutes les quantités subsidiaires. Les chaleurs de réaction et de dilution peuvent donc être calculées par différence avec une précision aussi grande que possible. L'estimation de la précision est indiquée par un certain nombre de chiffres significatifs. Cette précision n'est pas la précision absolue, mais la précision de la réaction particulière utilisée pour calculer le chiffre donné (voir colonne 4).

La précision absolue serait moindre que celle de la détermination la moins précise dans la série totale des réactions utilisées pour calculer la chaleur de formation à partir des éléments.

**Colonne 4. Méthode.**—Dans la colonne 4, on s'est efforcé d'indiquer d'une manière générale les réactions qui ont été employées pour le calcul des valeurs données. Voir la liste des abréviations ci-dessous. Dans cette colonne, les formules, par exemple MOH, indiquent que la chaleur de formation de  $\text{M}^+$  dépend de la valeur dans les tables de la chaleur de formation de solutions diluées de MOH. Les chiffres se trouvant dans cette colonne, par ex. 3,65, non précédés de l'abréviation Tr., indiquent la chaleur de dissolution déterminée expérimentalement, sur laquelle est basée la valeur indiquée dans la colonne 4, par ex. 3,65 kJ. Si les chiffres de cette colonne suivent le signe Tr., par ex. Tr. 0,8, cela indique que la chaleur de transition déterminée expérimentalement est par ex. 0,8 kJ. Des annotations indiquent la température à laquelle la réaction a été mesurée.

**Colonne 5. Références bibliographiques.**—Les références se rapportent à la publication originale, excepté dans le cas de Thomsen où les valeurs sont ordinairement tirées de son livre. Dans le cas où la méthode employée par l'auteur n'est pas calorimétrique, par ex. coefficient de température de F.E.M., etc., la référence est munie d'un astérisque. Si la référence contient des valeurs déterminées à d'autres températures, elle est suivie du signe, °. Si elle contient des valeurs concernant la chaleur partielle de dissolution, ou autres quantités thermiques "partielles" la référence est suivie du signe, †. On entend par quantité thermique partielle le rapport  $\frac{\partial \Delta Q}{\partial N_1}$  où  $N$  est la concentration de la substance, 1, en unités quelconques, ordinairement des fractions de molécules.

### Calculs

Pour calculer la tonalité thermique d'un processus entraînant la disparition d'une ou de plusieurs substances sous les états donnés par les tables, et l'apparition d'autres ou des mêmes substances sous des états donnés dans les tables: additionner les chaleurs de formation des corps produits par le processus dans les états finaux, et soustraire de ce nombre la somme des chaleurs de formation des substances réagissantes prises dans leurs états initiaux. Ainsi:

**Chaleur de réaction, ou tonalité thermique de la réaction.**— $\text{CaO (crist.)} + \text{H}_2\text{O (liq.)} = \text{Ca(OH)}_2\text{(crist.)}$ ,  $\Delta Q = Q_{\text{Ca(OH)}_2} - [Q_{\text{CaO}} + Q_{\text{H}_2\text{O}}] = 988 - (634,9 + 286,2) = 66,9 \text{ kJ}$ .

**Chaleur de dissolution.**—Si une détermination expérimentale directe est disponible, elle se trouvera dans la 3ème colonne sous la forme  $8,66_{400}^{18}$  qui indique que la chaleur de dissolution d'une mol gr. de substance dans 400 mol gr. d' $\text{H}_2\text{O}$  à  $18^\circ$  est de 8,66 kJ. Si la température ou la dilution n'est pas indiquée, la valeur précise n'a pas été donnée dans l'original et la valeur est à considérer pour la "température ambiante" et pour une solution "diluée." Si la chaleur de dissolution n'est pas directement donnée dans la colonne 4, elle peut être trouvée en écrivant la réaction et en procédant au calcul comme avec les chaleurs de réaction ci-dessus. Par ex., pour trouver la chaleur de dissolution de  $\text{SrCl}_2 \cdot 2\text{H}_2\text{O}$  dans 400 mol d'eau, il faut écrire  $\text{SrCl}_2 \cdot 2\text{H}_2\text{O} = \text{SrCl}_{2(400)} + 2\text{H}_2\text{O}$ ;  $\Delta Q = 874,7 + 2 \times 286,2 - 1438,4 = 8,7 \text{ kJ}$ .

**Chaleur de dilution.**—La chaleur moléculaire intégrale de dilution c.à.d. la chaleur obtenue en diluant avec  $y$  mol d' $\text{H}_2\text{O}$ , une solution d'une mol gr. de la substance dans  $x$  mol d' $\text{H}_2\text{O}$ , est l'excès de la chaleur de formation d'une mol gr. de la substance dans la solution finale sur sa chaleur de formation dans la solution initiale. Ainsi: la chaleur de dilution d'une mol d' $\text{H}_2\text{SO}_4$  dans 99 mol d'eau, portée à une mol d' $\text{H}_2\text{SO}_4$  dans 799 mol d'eau est égale à  $871,6 - 867,8 = 3,8 \text{ kJ}$ .

**Chaleur de transition.**—Si les deux formes de la substance peuvent être obtenues à  $18^\circ$  et sous une atmosphère, il faut



soustraire la chaleur de formation de la forme finale de celle de la forme initiale. Dans le cas de transitions qui ne peuvent être réalisées sous une atmosphère qu'à des températures différentes de 18°, la chaleur de transition se trouvera dans la colonne 3 après l'abréviation Tr. Par ex. la chaleur de transition de  $Mn_{\alpha}$  à  $Mn_{\beta}$  est donnée sous la forme  $Mn_{\alpha} \dots Tr.; 5,5_{\beta}^{1100}$ , qui signifie que 5,5 kJ de chaleur sont dégagés lorsqu'un atome gramme de  $\alpha$ -manganèse se transforme en  $\beta$ -manganèse à 1100°.

**Chaleurs d'ionisation.**—La chaleur de formation d'une solution complètement ionisée d'une substance donnée peut être considérée comme la somme des chaleurs de formation de ses ions. C'est pourquoi, si l'on connaît la chaleur de formation d'une solution complètement ionisée et celles de tous ses ions sauf un, la chaleur de formation de ce dernier ion peut être calculée. Cette méthode a été utilisée pour calculer les chaleurs de formation des ions données dans la table, la chaleur de formation de  $H^+$  étant arbitrairement prise comme zéro. Inversement, connaissant les chaleurs de formation des ions, on peut trouver la chaleur de formation d'une solution diluée d'un électrolyte fort, par addition des chaleurs de formation de ses ions; par ex., la chaleur de formation de  $(NH_4)_2SeO_4(aq.) = 2QNH_4^+ + QSeO_4^{2-} = 2 \times 132,7 + 613 = 878,4$  kJ. D'une façon analogue, la chaleur d'ionisation d'un électrolyte faible peut être calculée en totalisant les chaleurs de formation de ses ions et en soustrayant du résultat sa chaleur de formation; par ex.,  $H_2O = OH^- + H^+$ ;  $\Delta Q = QOH^- + QH^+ - QH_2O = 228,2 + 0 - 286,2 = -58,0$  kJ.

### ABRÉVIATIONS, SIGNES, FORMES

#### Abréviations

amorp.	Amorphe, état cryptocristallin, ou état solide mal défini.
aq.	Solution aqueuse diluée.
c	Macrocrystallin.
coll.	Gel ou sol colloïdal.
Def.	État typé.
dil.	Dépend d'une chaleur de dilution.
dissoc.	Dépend d'une chaleur de dissociation.
extrap.	Extrapolé.
gls.	Un verre ou un solide provenant d'un liquide surfondu.
(ideal)	Dans la condition indiquée par la formule, par ex., pour $N_2O_4$ le mot "(ideal)" dans la colonne 2 indique que la chaleur de formation est celle pour un gaz composé seulement de molécules de $N_2O_4$ .
liq.	Liquide.
mix.	Chaleur de mélange.
N	De la chaleur de neutralisation.
ppt.	Précipité ou de la chaleur de précipitation.
sat.	En solution saturée dans l' $H_2O$ .

#### Signes dans la table

*	Par méthodes indirectes non calorimétriques.
&	Par plusieurs méthodes différentes.
$\infty$	Dans une quantité infinie d' $H_2O$ à moins d'une autre indication.

#### SIGNES DANS LA COLONNE DES REF. BIBL.

*	Par méthodes indirectes non calorimétriques.
†	Comprend la détermination ou la compilation de quantités "partielles."
°	Comprend des déterminations à des températures différentes de 18°.

#### Formes

+X <sub>2</sub>	Déduit de la chaleur de réaction avec X <sub>2</sub> .
Tr.; 0,92 <sub>(i)</sub>	La chaleur de transition dans la forme cristalline I est 0,92 kJ à 427°.

### EXPOSANTS AINSI

2600<sup>34</sup> Un exposant indique la température.

### INDICES

365 <sub>100</sub>	La dilution de la solution finale est de 100 mol $H_2O$ par mol gr. de substance.
365 <sub>KOH</sub>	Dans une solution diluée de KOH.
365 <sub>KOH(100)</sub>	Le solvant est constitué par une mol KOH dans 100 mol $H_2O$ .
365 <sub>24 KCN</sub>	Le solvant est constitué par une solution contenant 24 mol de KCN par mol de corps dissout.

### Exemples Explicatifs

$H_2O$ .—L'information donnée dans les colonnes 2 et 3 est équivalente à ce qui suit: "Lorsque 2 atomes gr. (2,0154 g) du gaz hydrogène ( $H_2$ ) à 18° et sous 1 atm. réagissent avec un atome gr. (16,00 g) d'oxygène à 18° et sous 1 atm. pour produire une mol gr. (18,0154 g) d' $H_2O$  liquide à 18° et une atm., il y a dégagement de 286,2 kJ de chaleur." Ceci est équivalent (voir les facteurs de conversion donnés ci-dessous) à  $0,23895 \times 286,2 = 68,39$  kg-cal<sub>18</sub>, etc.

$Cl^-$ .—L'information donnée dans les colonnes 2, 3 et 4 est équivalente à ce qui suit: "La chaleur de formation d'une solution complètement ionisée contenant une mol gr. (35,458 g) de  $Cl^-$  et la quantité équivalente d'un ion positif (par ex. une solution de  $Cl^- + H^+ = HCl_{\infty}$ ) est égale à la somme de la chaleur de formation de  $Cl^-$ ,  $Q = 165,55$  et de  $H^+$ ,  $Q = 0$ , qui est  $Q = 165,55$  kJ."

$H_2O_{2(200)}$ .—L'information donnée dans les colonnes 2 et 3 est équivalente à ce qui suit: "Lorsque 2 atomes grammes ( $2 \times 1,0077$  g) du gaz hydrogène à 18° et sous 1 atm. réagissent avec 2 atomes gr. ( $2 \times 16,00$  g) du gaz oxygène à 18° et sous 1 atm. et que le produit 1 mol gr. (34,0154 g) d' $H_2O_2$ , est dissout dans 200 mol gr. d' $H_2O$  ( $18,0154 \times 200 = 3603,08$  g), il y a dégagement de 188,2 kJ de chaleur." La solution résultante contient une mol gr.  $H_2O_2$  dans 200 mol gr. d' $H_2O$ . Le rapport moléculaire de l'eau dans la solution est ainsi de 200, le rapport moléculaire de  $H_2O_2$  est 0,005. La fraction moléculaire de  $H_2O_2$  est  $\frac{1}{200 + 1} = 0,004925$ ; celle de  $H_2O$  est  $\frac{200}{200 + 1} = 0,995075$ . La concentration en mol gr.  $H_2O_2$  par 1000 g d'eau est de  $\frac{1000}{200 \times 18,0154} = 0,2775$ . La solution contient  $\frac{34,0154 \times 100}{(200 \times 18,0154) + 34,0154} = 0,935$  pourcent poids de  $H_2O_2$ .

### ERKLÄRUNG

Anordnung.—Standard, siehe Bd. III, S. viii.

Reihe 1. Formel.—Die Formel, welche in der ersten Reihe erscheint, bezeichnet den Stoff dessen Bildungswärme per 1 G.F.G. (Gramm-Formel-Gewicht) in der Reihe 3 erscheint. Polymorphe Formen, oder Zustände, die eine besondere Beschreibung erfordern, als die, welche in der Reihe 2 angegeben ist, sind durch willkürlich gewählte Zeichen in Klammern angeführt, z.B. durch griechische Buchstaben, römische Zahlen, oder Bemerkungen. Die polymorphen Formen sind weiter durch die Umwandlungstemperatur gekennzeichnet, welche in der Reihe 4 als hinaufgesetzter Index zu Tr. angegeben ist.

Reihe 2. Physikalischer Zustand.—Für jeden Stoff ist der physikalische Zustand, auf den sich die Bildungswärme bezieht, in der Reihe 2 angegeben. Abkürzungen siehe unten. Alle Zustände gelten für 1 Atmosphäre und 18°C, wenn nicht durch hinaufgesetzte Zeichen in der Reihe 3 etwas anderes angegeben ist. Zahlen oder Formeln in der Reihe 2 bedeuten, dass der Stoff in Lösung sich befindet: es ist 1 G.F.G. gelöst in X G.F.G. des Lösungsmittels. Wasser ist das Lösungsmittel dort, wo nichts besonderes bezeichnet ist. Ist das Lösungsmittel gegeben, aber



die Konzentration nicht festgestellt, so ist die Lösung "verdünnt." Z.B. 200 = "1 G.F.G. von dem Stoffe (Reihe 2) ist gelöst in  $200 \times 18 \text{ g H}_2\text{O}$ ;"  $200_{\text{C}_2\text{H}_5\text{OH}}$  = "1 G.F.G. des Stoffes gelöst in  $200 \times 46 \text{ g C}_2\text{H}_5\text{OH}$ ;"  $\text{CS}_2$  = "1 G.F.G. des Stoffes gelöst in einer grossen Menge  $\text{CS}_2$ ;" u.s.w.

**Reihe 3. Bildungswärme.**—Die Zahlen in der Reihe 3 bedeuten Kilojoule, kj (absolut), als diejenige Wärmemenge, welche entwickelt wird, wenn 1 G.F.G. des Stoffes (in der Reihe 1 angegeben) in dem in der Reihe 2 angegebenen physikalischen Zustand, aus dem im Normalzustand befindlichen Elementen bei  $18^\circ\text{C}$  und bei 1 Atmosphäre, entsteht. Entsprechend des gegebenen Definition, ist die Bildungswärme eines Elementes im Normalzustande Null. Der Normalzustand irgend eines Elementes kann so gefunden werden und auch durch die Abkürzung "Def." in der Reihe 3, gegenüber dem Zeichen des Elementes. Die Bildungswärmen von Ionen gründen sich auf der Basis, dass für  $\text{H}^+$ , willkürlich Null gesetzt wird, sie gelten für verdünnte Lösungen vollständig ionisierter Elektrolyte.

**Genauigkeit.**—Alle in dieser Tabelle angegebenen Werte, wurden nach dem im Original befindlichen experimentellen Daten neu gerechnet, indem festgelegte Werte für alle Hilfsgrössen benützt wurden. Die Reaktions- und Verdünnungs-Wärmen können also durch Differenzen berechnet werden, deren Genauigkeit so weit als bekannt geht. Die geschätzte Genauigkeit ist durch die Anzahl der gross geschriebenen Zahlen ausgedrückt. Diese Genauigkeit ist nicht die absolute Genauigkeit, aber die Genauigkeit der Teilreaktion die verwendet worden ist, um die der angegebenen Zahl zu berechnen (siehe Reihe 4). Die absolute Genauigkeit wird kleiner sein, als die wenigst genaue Bestimmung in der gesamten Kette der Reaktionen, die gebraucht worden sind, um die Bildungswärmen aus den Elementen zu berechnen.

**Reihe 4. Methode.**—In dieser Reihe ist ein Versuch gemacht worden, in einer allgemeinen Weise die Reaktionen zu verzeichnen, die bei der Berechnung der angegebenen Werte verwendet worden sind. Abkürzungen siehe unten. Formeln in dieser Reihe, z.B.  $\text{MOH}$ , zeigen an, dass die Bildungswärme von  $\text{M}^+$  von den in der Tafel Angaben der Bildungswärme der verdünnten Lösung von  $\text{MOH}$  abhängt. Zahlen, z.B. 3,65, in dieser Reihe, welchen nicht ein Tr. vorausgeht, geben die experimentell bestimmte Lösungswärme an, auf Grund derer die Zahl in der Reihe 3 ruht. In diesem Zusammenhang bedeutet die Zahl 3,65, dass die experimentell bestimmte Lösungswärme 3,65 kj beträgt. Zahlen in dieser Reihe, welche Tr. folgen, z.B. Tr. 0,8, bedeuten die experimentell bestimmte Umwandlungswärme in kj, (0,8 kj). Hinaufgesetzte Indizes bedeuten die Temperatur bei welcher die Reaktion gemessen worden ist.

**Reihe 5. Literatur-Verzeichnis.**—Die Hinweise beziehen sich immer auf die Originalarbeit, ausser im Falle von Thomsen, wo gewöhnlich die Werte aus seinem Buche genannt werden. Sind vom Autor nicht-calorimetrische Methoden angewendet worden z.B. Temperaturkoeffizient der elektromotorischen Kraft, u.s.w., so ist die Literaturangabe mit einem Stern versehen; enthält sie Werte die bei einer anderen Temperatur bestimmt worden sind, so erhält sie das Zeichen, °, oder enthält sie partielle Lösungswärmen oder andere "partielle" Werte einer thermischen Grösse, wird sie mit dem Zeichen, †, versehen. Unter partielle thermische Grössen versteht man den Ausdruck  $\frac{\partial \Delta Q}{\partial N_1}$  in welchem  $N_1$  die Konzentration des Stoffes 1 in irgend einer Einheit, gewöhnlich in Molbrüchen, bedeutet.

#### Berechnungen

Die Wärmetönung irgend eines Prozesses, der das Verschwinden eines Stoffes oder mehrerer, von einem in der Tabelle angegebenen Zustand und das Auftreten anderen Stoffen, oder derselben Stoffe, in einem Zustande der in der Tabelle angegeben, zur Folge hat, bestimmt man, wie folgt: Man addiere die Bildungswärmen der

Reaktionsprodukte des Prozesses in dem Endzustand zusammen und subtrahiert davon die Summe der Bildungswärmen der Ausgangsprodukte in ihren Ausgangszuständen, z.B.

**Reaktionswärme.**— $\text{CaO (krist.)} + \text{H}_2\text{O (flüss.)} = \text{Ca(OH)}_2 \text{ (krist.)}$ ,  $\Delta Q = Q_{\text{Ca(OH)}_2} - [Q_{\text{CaO}} + Q_{\text{H}_2\text{O}}] = 988 - [634,9 + 286,2] = 66,9 \text{ kj}$ .

**Lösungswärme.**—Ist eine direkte experimentelle Bestimmung vorhanden, findet man in der Reihe 3 die Form  $8,66_{400}^{18}$ , das bedeutet, die Lösungswärme für 1 G.F.G. des Stoffes in 400 Molen Wasser bei  $18^\circ\text{C}$  ist 8,66 kj. Ist die Temperatur oder die Verdünnung nicht angegeben, so ist der genaue Wert nicht im Original zu finden, der Wert gilt dann für "Zimmertemperatur" und eine "verdünnte" Lösung. Ist die Lösungswärme nicht direkt in der Reihe 4 angegeben, so kann man sie finden, wenn man die Reaktion niederschreibt und dann so vorgeht, wie oben, bei der Bestimmung der Reaktionswärmen. Um z.B. die Lösungswärme von  $\text{SrCl}_2 \cdot 2\text{H}_2\text{O}$  in 400 Molen Wasser zu finden, schreibe man,  $\text{SrCl}_2 \cdot 2\text{H}_2\text{O} = \text{SrCl}_2_{(400)} + 2\text{H}_2\text{O}$ ;  $\Delta Q = 874,7 + 2 \times 286,2 - 1438,4 = 8,7 \text{ kj}$ .

**Verdünnungswärme.**—Die molare integrale Verdünnungswärme ist die Wärme, welche bei der Verdünnung mit  $y$  Molen Wasser, einer Lösung von 1 G.F.G. des Stoffes in  $x$  Molen Wasser, entsteht. Sie ist der Überschuss der Bildungswärme die entsteht, wenn 1 G.F.G. des Stoffes zur Endkonzentration gelöst wird, gegen die Bildungswärme bei der Herstellung der Anfangskonzentration. Z.B. die Verdünnungswärme eines Moles  $\text{H}_2\text{SO}_4$  in 99 Molen Wasser zu 1 Mol  $\text{H}_2\text{SO}_4$  in 799 Molen Wasser ist  $871,6 - 867,8 = 3,8 \text{ kj}$ .

**Umwandlungswärme.**—Können beide Formen des Stoffes bei  $18^\circ\text{C}$  und 1 Atmosphäre erhalten werden, subtrahiere man die Bildungswärme der Endform von der der Anfangsform. Für Umwandlungen, die bei 1 Atmosphäre nur bei einer von  $18^\circ\text{C}$  verschiedener Temperatur beobachtet werden können, kann man die Umwandlungswärme in der Reihe 3 nach der Abkürzung Tr. finden. Z.B. ist die Umwandlungswärme von  $\text{Mn}_\alpha$  zu  $\text{Mn}_\beta$  durch die Form  $\text{M}_\alpha \dots \text{Tr.}$ ;  $5,5_{1100}^{18}$  gegeben, das bedeutet, bei  $1100^\circ\text{C}$ , wenn die Umwandlung von 1 Grammatom  $\alpha$ -Mangan in  $\beta$ -Mangan vor sich geht, werden 5,5 kj entwickelt.

**Ionisationswärmen.**—Die Bildungswärme einer vollständig ionisierten Lösung eines Stoffes kann betrachtet werden, als die Summe der Bildungswärmen seiner Ionen. Deshalb, kennt man die Bildungswärme einer vollständig ionisierten Lösung und ist die Bildungswärme aller Ionen bis auf eines bekannt, so kann die Bildungswärme des anderen Ions berechnet werden. Diese Methode ist verwendet worden um die, in der Tabelle angegebenen, Bildungswärmen für die Ionen zu berechnen. Die Bildungswärme für das Wasserstoff-Ion  $\text{H}^+$  wurde willkürlich Null gesetzt. Umgekehrt, kennt man die Bildungswärmen der Ionen, kann man die Bildungswärmen der verdünnten Lösung eines starken Elektrolyten durch Addition der Bildungswärmen seiner Ionen finden. Es ist z.B. die Bildungswärme von  $(\text{NH}_4)_2\text{SeO}_4(\text{aq.}) = 2Q_{\text{NH}_4^+} + Q_{\text{SeO}_4^{2-}} = 2 \times 132,7 + 613 = 878,4 \text{ kj}$ . Ähnlich, kann man die Ionisationswärme eines schwachen Elektrolyten berechnen, indem man von der Summe der Ionisationswärmen seiner Ionen, die Bildungswärmen desselben subtrahiert. Z.B.  $\text{H}_2\text{O} = \text{OH}^- + \text{H}^+$ ;  $\Delta Q = Q_{\text{OH}^-} + Q_{\text{H}^+} - Q_{\text{H}_2\text{O}} = 228,2 + 0 - 286,2 = -58,0 \text{ kj}$ .

#### ABKÜRZUNGEN, ZEICHEN UND FORMEN

##### Abkürzungen

amorp.	Amorph, kryptokristallinisch, oder schlecht definierter Zustand.
aq.	Verdünnte wässrige Lösung.
c	Makrokristallin.
coll.	Kolloidales Gel oder Sol.
Def.	Normalzustand.



dil.	Hängt von einer Verdünnungswärme ab.
dissoc.	Hängt von einer Dissoziationswärme ab.
extrap.	Extrapoliert.
gls.	Ein Glas oder eine feste unterkühlte Flüssigkeit.
(ideal)	Betrifft die Bedingungen, welche die Formel ausdrückt, z.B. für $N_2O_4$ bedeutet das Wort "(ideal)" in der Reihe 2, dass die Bildungswärme für ein Gas gilt, welches nur aus $N_2O_4$ Molekeln besteht.
liq.	Flüssig.
mix.	Mischungswärme.
N	Von der Neutralisationswärme.
ppt.	Niedergeschlagen, oder von der Niederschlagswärme.
sat.	In wässriger gesättigter Lösung.

## Zeichen

## IN DER TAFEL

*	Durch eine indirekte nicht kalorimetrische Methode.
&	Durch mehrere verschiedene Methoden.
∞	In einer unendlich grossen Menge Wasser, wenn nichts anderes angegeben.

## IN DER REIHE DER LITERATURANGABE

*	Durch eine indirekte nicht kalorimetrische Methode.
†	Enthält Messungen oder Sammlungen von "partielle" Grössen.
°	Enthält Messungen bei einer von 18°C verschiedenen Temperatur.

## Formen

+X <sub>2</sub>	Abgeleitet von Reaktionswärme mit X <sub>2</sub> .
Tr.; 0,92 <sup>427</sup> <sub>(1)</sub>	Die Umwandlungswärme zur Kristallform, I, ist 0,92 kJ bei 427°C

## HINAUFGESETZTER INDEX

2600 <sup>35</sup>	Der Index bedeutet die Temperatur.
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## HINUNTERGESETZTER INDEX

365 <sub>100</sub>	Der Index bedeutet, dass die Verdünnung der Endlösung ist 100 Mole Wasser auf 1 G.F.G. des Stoffes.
365 <sub>KOH</sub>	In einer verdünnten KOH-Lösung.
365 <sub>KOH(100)</sub>	Das Lösungsmittel ist 1 Mol KOH auf 100 Mole Wasser.
365 <sub>24 KCN</sub>	Das Lösungsmittel ist eine Lösung, welche 24 Mole von KCN pro 1 Mol des gelösten Stoffes enthält.

## Beispiele

$H_2O$ .—Die in der Reihe 2 und 3 gegebenen Daten entsprechen dem folgendem: "Wenn 2 Grammatome, (2,0154 g) Wasserstoffgas ( $H_2$ ), bei 18°C und 1 Atmosphäre mit 1 Grammatom (16 g) Sauerstoff (O), bei 18°C und 1 Atmosphäre, miteinander reagieren und dabei 1 G.F.G. flüssiges Wasser (18,0154 g) bei 18°C und 1 Atmosphäre geben, so werden 286,2 kJ Wärme entwickelt." Das ist äquivalent (siehe die unten angegebenen Umrechnungsfaktoren)  $0,23895 \times 286,2 = 68,39 \text{ kg-cal}_{18}$ , u.s.w.

$Cl^-$ .—Die Daten, welche in der Reihe 2 und 3 gegeben sind, entsprechen dem folgendem: "Die Bildungswärme einer vollständig ionisierten Lösung, die 1 G.F.G. von  $Cl^-$  enthält (35,458 g) und die gleiche Menge eines positiven Ions (z.B. eine Lösung von  $Cl^- + H^+ = HCl_{\infty}$ ), ist die Summe der Bildungswärmen von  $Cl^-$ ,  $Q = 165,55$ , und von  $H^+$ ,  $Q = 0$ , zusammen also 165,55 kJ."

$H_2O_{2(200)}$ .—Die Daten, welche in der Reihe 2 und 3 gegeben sind, entsprechen dem folgendem: "Wenn 2 Grammatome ( $2 \times 1,0077 \text{ g}$ ) Wasserstoffgas bei 18°C und 1 Atmosphäre mit 2 Grammatomen ( $2 \times 16 \text{ g}$ ) Sauerstoffgas von 18°C und 1 Atmosphäre, reagieren und das Reaktionsprodukt 1 G.F.G. (34,0154 g)  $H_2O_2$  gelöst in 200 G.F.G. von  $H_2O$  ( $18,0154 \times 200 = 3603,08 \text{ g}$ ) ist, so werden 188,2 kJ als Reaktionswärme frei." Die sich ergebende Lösung enthält 1 G.F.G. von  $H_2O_2$  in 200 G.F.G. Wasser. Das Molenverhältnis des Wassers ist also in der Lösung 200, das Molenverhältnis des  $H_2O_2$  ist 0,005. Der Molenbruch für

$H_2O_2$  ist  $\frac{1}{200 + 1} = 0,004925$ ; für  $H_2O$   $\frac{200}{200 + 1} = 0,995075$ . Die Konzentration in G.F.G.  $H_2O_2$  pro 1000 g Wasser ist  $\frac{1000}{200 \times 18,0154} = 0,2775$ . Die Lösung enthält  $\frac{34,0154 \times 100}{(200 \times 18,0154) + 34,0154} = 0,935$  Gewichtsprozent auf  $H_2O_2$ .

## SPIEGAZIONE

Disposizione.—Standard, vedi Vol. III, p. viii.

Colonna 1. Formula.—Le formule contenute nella colonna 1 indicano le sostanze di cui nella colonna 3 sono riportati i calori di formazione per p.f.g. (peso in grammi corrispondente alla formula). Le forme polimorfiche o gli stati i quali richiedono per essere definiti indicazioni più ampie di quelle riportate nella colonna 2 sono indicati con segni arbitrari tra parentesi, p.e. con lettere greche, numeri romani, o altri qualificativi. Le forme polimorfiche sono inoltre indicate con la temperatura di trasformazione che è riportata nella colonna 4 dopo l'abbreviazione Tr.

Colonna 2. Stato fisico.—Per ogni sostanza, lo stato fisico al quale si riferisce il calore di formazione è indicato nella colonna 2. Vedi più oltre la lista delle abbreviazioni. Tutti gli stati, quando non è diversamente indicato nella colonna 3, sono considerati alla pressione di 1 atmosfera e alla temperatura di 18°C. Le formule nella colonna 2 indicano che la sostanza è in soluzione e che un p.f.g. è disciolto in X p.f.g. di solvente. Dove il solvente non è indicato, si intende che si tratta dell'acqua. Dove è indicato il solvente, ma non la concentrazione, s'intende che si tratta di soluzione diluita. Così 200 = "1 p.f.g. della sostanza (della col. 1) disciolta in 200  $\times$  18 g di  $H_2O$ ;"  $200_{C_2H_5OH}$  = "1 p.f.g. della sostanza disciolta in 200  $\times$  46,0 g di  $C_2H_5OH$ ;"  $CS_2$  = "1 p.f.g. della sostanza disciolta in una grande quantità di  $CS_2$ ," etc.

Colonna 3. Calore di formazione.—I valori della colonna 3 sono in numero di kilojoules, kJ (assoluti) di calore *svolti* quando un p.f.g. della sostanza (che figura nella colonna 1 e nello stato indicati nella colonna 2) si forma dagli elementi considerati nelle condizioni normali alla temperatura di 18° e alla pressione di 1 atm. Secondo la definizione data sopra il calore di formazione di un elemento nel suo stato normale è 0. Lo stato normale di un elemento qualsiasi può essere riconosciuto da questo fatto e dall'abbreviazione "Def." nella colonna 3 in corrispondenza del simbolo dell'elemento. I calori di formazione degli ioni sono riferiti al valore arbitrario 0 per  $H^+$  e si riferiscono a soluzioni diluite di elettroliti completamente ionizzati.

Precisione.—Tutti i valori riportati in questa tabella sono stati ricalcolati dai dati originali sperimentali usando valori ben vagliati per tutte le quantità sussidiarie. I calori di reazione e di diluizione possono quindi essere calcolati per differenza con l'accuratezza maggiore che è possibile. La precisione che si può raggiungere è indicata dal numero delle cifre significative. Questa precisione non è quella assoluta; ma la precisione della particolare reazione usata per calcolare il valore adottato (v. colonna 4). La precisione assoluta è inferiore a quella della determinazione meno accurata nella serie di reazioni utilizzata per il calcolo del calore di formazione a partire dagli elementi.

Colonna 4. Metodo.—Nella colonna 4 si è fatto il tentativo di indicare in una maniera generale le reazioni utilizzate per il calcolo dei valori riportati. Vedi la lista delle abbreviazioni più oltre. Le formule di questa colonna per es.  $MOH$ , indicano che il calore di formazione di  $M^+$  dipende dal valore che nella tabella è riportato per il calore di formazione della soluzione diluita di  $MOH$ . Le cifre di questa colonna, p. e. 3,65; quando non sono precedute dall'abbreviazione Tr., indicano il valore sperimentale del calore di soluzione sul quale è basato il valore della colonna 4, p.e. 3,65 kJ. I numeri di questa colonna preceduti da Tr., per es. Tr. 0,8; indicano il calore di trasformazione determinato speri-



mentalmente, per es. 0,8 kj. I numeri scritti sopra indicano le temperature alle quali le reazioni sono state misurate.

**Colonna 5. Letteratura.**—La citazione si riferisce alla pubblicazione originale; solo i valori del Thomsen sono generalmente presi dal suo libro. Quando il metodo usato dall'autore non è quello calorimetrico (come per es. quando il valore è dedotto dal coefficiente di temperatura della F.E.M., etc.) la citazione è munita di asterisco. Se la citazione contiene valori determinati ad altre temperature, è seguita dal simbolo, °, e se contiene valori per il calore parziale di soluzione o altre quantità termiche "parziali," la citazione è seguita dal simbolo, †. Per quantità termiche parziali si intendono i valori  $\frac{\partial \Delta Q}{\partial N_1}$  dove  $N_1$  è la concentrazione della sostanza, 1, in qualsiasi unità, generalmente frazioni di grammimolecole.

#### Calcolo

Per calcolare il calore di qualsiasi processo che implica la scomparsa di una o più sostanze negli stati indicati nella tabella, e la comparsa di altre o delle stesse sostanze negli stati indicati nella tabella, si sommano i calori di formazione dei prodotti finali e dalla somma si sottraggono i calori di formazione delle sostanze reagenti nei loro stati iniziali. Per esempio:

**Calore di reazione.**— $\text{CaO (crist.)} + \text{H}_2\text{O (liq.)} = \text{Ca(OH)}_2 \text{ (crist.)}$ ,  $\Delta Q = Q_{\text{Ca(OH)}_2} - [Q_{\text{CaO}} + Q_{\text{H}_2\text{O}}] = 988 - [634,9 + 286,2] = 66,9 \text{ kj.}$

**Calore di soluzione.**—Se esiste un valore sperimentale, lo si trova nella colonna 3 sotto la forma  $8,66_{400}^{18}$  la quale indica che il calore di soluzione di un p.f.g. della sostanza in 400 moli di  $\text{H}_2\text{O}$  a  $18^\circ$  è 8,66 kj. Se la temperatura o la diluizione non sono indicate, vuol dire che non lo sono nel lavoro originale, ed i valori si riferiscono alla temperatura ambiente e a soluzioni diluite. Se il calore di soluzione non è direttamente indicato nella colonna 4, lo si può stabilire scrivendo la reazione e procedendo nel calcolo come è indicato sopra per i calori di reazione. Per es., si supponga di voler calcolare il valore di soluzione di  $\text{SrCl}_2 \cdot 2\text{H}_2\text{O}$  in 400 moli di acqua; allora si ha:  $\text{SrCl}_2 \cdot 2\text{H}_2\text{O} = \text{SrCl}_2(400) + 2\text{H}_2\text{O}$ ;  $\Delta Q = 874,7 + 2 \times 286,2 - 1438,4 = 8,7 \text{ kj.}$

**Calore di diluizione.**—Il calore molecolare integrale di diluizione (e cioè il calore che si ha nel diluire con  $y$  moli di  $\text{H}_2\text{O}$  una soluzione di un p.f.g. della sostanza in  $x$  moli di  $\text{H}_2\text{O}$ ), è la differenza tra il calore di formazione di un p.f.g. della sostanza nella soluzione finale e quello nella soluzione iniziale. Per es. il calore che si ha diluendo una soluzione di una mole di  $\text{H}_2\text{SO}_4$  in 99 moli di acqua fino a raggiungere la concentrazione di una mole di  $\text{H}_2\text{SO}_4$  in 799 moli di acqua è  $871,6 - 867,8 = 3,8 \text{ kj.}$

**Calore di trasformazione.**—Se tutte le due forme della sostanza possono ottenersi a  $18^\circ$  e alla pressione di 1 atmosfera, si sottrae il calore di formazione della forma finale da quello della forma iniziale. Per le trasformazioni che possono effettuarsi al di sotto di 1 atm. soltanto a temperature diverse da  $18^\circ$ , il calore di trasformazione si trova nella colonna 3 dopo l'abbreviazione Tr. Per es., il calore di trasformazione da  $\text{Mn}_\alpha$  a  $\text{Mn}_\beta$  è indicato così:  $\text{Mn}_\alpha \dots \text{Tr.; } 5,5_{1100}^{1100}$ , il che significa che quando un grammo atomo di  $\alpha$ -manganese si trasforma in  $\beta$ -manganese a  $1100^\circ$  si svolgono 5,5 kj.

**Calore di ionizzazione.**—Il calore di formazione di una soluzione completamente ionizzata di una sostanza può considerarsi come la somma dei calori di formazione dei suoi joni. Quindi se si conosce il calore di formazione di una soluzione completamente ionizzata, e si conosce o ammette quello di tutti i suoi joni meno uno, si può calcolare il calore di formazione di quest'ultimo. Questo metodo è stato usato per calcolare il calore di formazione degli joni dati nella tabella, assumendo arbitrariamente eguale a 0 il calore di formazione di  $\text{H}^+$ . Inversamente conoscendo i calori di formazione degli joni si può stabilire il calore di formazione di una soluzione diluita di un elettrolita forte aggiungendo

i calori di formazione dei suoi joni: per es., il calore di formazione di  $(\text{NH}_4)_2\text{SeO}_4 \text{ (aq.)} = 2 Q_{\text{NH}_4^+} + Q_{\text{SeO}_4^{2-}} = 2 \times 132,7 + 613 = 878,4 \text{ kj.}$  Similmente il calore di ionizzazione di un elettrolita debole si può calcolare sommando i calori di formazione dei suoi joni e sottraendo poi il suo calore di formazione: per es.,  $\text{H}_2\text{O} = \text{OH}^- + \text{H}^+$ ,  $\Delta Q = Q_{\text{OH}^-} + Q_{\text{H}^+} - Q_{\text{H}_2\text{O}} = 228,2 + 0 - 286,2 = -58,0 \text{ kj.}$

#### ABBREVIAZIONI, SEGNI E FORMULE

##### Abbreviazioni

amorp.	Amorfo, criptocristallino o stato solido mal definito.
aq.	Soluzione acquosa diluita.
c	Macrocrystallino.
coll.	Gelo o solo colloidale.
Def.	Condizioni normali.
dil.	Dedotto da un calore di diluizione.
dissoc.	Dedotto da un calore di dissociazione.
extrap.	Estrapolato.
gls.	Un vetro o un liquido sopraraffreddato.
(ideal)	Nelle condizioni indicate dalla formula, p. es. per $\text{N}_2\text{O}_4$ la parola "(ideal)" nella colonna 2 indica che il calore di formazione si riferisce ad un gas formato soltanto di molecole $\text{N}_2\text{O}_4$ .
liq.	Liquido.
mix.	Calore di mescolamento.
N	Dal calore di neutralizzazione.
ppt.	Precipitato o dal calore di precipitazione.
sat.	In soluzione satura in $\text{H}_2\text{O}$ .

##### Segni

##### NELLA TABELLA

*	Con metodo indiretto non calorimetrico.
&	Con parecchi metodi differenti.
∞	In una quantità infinita di $\text{H}_2\text{O}$ se non è altrimenti indicato.

##### NELLA COLONNA DELLE CITAZIONI

*	Con metodi indiretti non calorimetrici.
†	Include la determinazione o la compilazione di quantità "parziali."
°	Include determinazioni a temperature diverse da $18^\circ$ .

##### Forme

+X <sub>2</sub>	Dedotto da calore di reazione con X <sub>2</sub> .
Tr.; 0,92 <sub>427</sub> <sup>427</sup>	Il calore di trasformazione nella forma cristallina "I" è 0,92 kj a $427^\circ$ .

##### NUMERI SOPRASCritti

2600 <sup>26</sup>	Un numero soprascritto indica la temperatura.
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##### NUMERI SOTTOSCRITTI

365 <sub>100</sub>	La diluizione della soluzione finale è 100 moli di $\text{H}_2\text{O}$ per p.f.g. di sostanza.
365 <sub>KOH</sub>	In una soluzione diluita di KOH.
365 <sub>KOH(100)</sub>	Il solvente è una mole di KOH in 100 moli di $\text{H}_2\text{O}$ .
365 <sub>24 KCN</sub>	Il solvente è una soluzione contenente 24 moli di KCN per mole di sostanza disciolta.

##### Esempi Illustrativi

**$\text{H}_2\text{O}$ .**—Le notizie riportate nelle colonne 2 e 3 significano quanto segue: "Quando due grammi atomi (g 2,0154) di idrogeno gassoso ( $\text{H}_2$ ) a  $18^\circ$  e una atm. reagiscono con un grammo atomo (g 16,00) di ossigeno gas a  $18^\circ$  e una atm., per produrre un p.f.g. (g 18,0154) di  $\text{H}_2\text{O}$  liquida a  $18^\circ$  e a una atm., si sviluppano 286,2 kj." Questi equivalgono (vedi i fattori di conversione dati più sotto) a  $0,23895 \times 286,2 = 68,39 \text{ kg-cal}_{18}$ .

**$\text{Cl}^-$ .**—Le notizie date nelle colonne 2, 3 e 4 significano quanto segue. "Il calore di formazione di una soluzione completamente ionizzata contenente un p.f.g. (g 35,458) di  $\text{Cl}^-$  e la quantità equivalente di un jone positivo qualsiasi (per es. una soluzione di



$\text{Cl}^- + \text{H}^+ = \text{HCl}_{(g)}$  è la somma del calore di formazione di  $\text{Cl}^-$ ,  $Q = 165,55$ , e di  $\text{H}^+$ ,  $Q = 0$ , e cioè  $Q = 165,55 \text{ kJ}$ ."

$\text{H}_2\text{O}_{(200)}$ .—I numeri riportati nelle colonne 2 e 3 significano quanto segue. "Quando due gr. atomi ( $2 \times 1,0077$ ) di idrogeno gassoso a  $18^\circ$  e a una atm. reagiscono con 2 grammi atomi ( $2 \times 16,00$ ) di ossigeno gassoso a  $18^\circ$  e a una atm., e il prodotto, 1 p.f.g. ( $g$  34,0154) di  $\text{H}_2\text{O}_2$  si scioglie in 200 p.f.g. di  $\text{H}_2\text{O}$  ( $18,0154 \times 200 = 3603,08 \text{ g}$ ) si sviluppano 188,2 kJ." La soluzione risultante contiene un p.f.g. di  $\text{H}_2\text{O}_2$  in 200 p.f.g. di  $\text{H}_2\text{O}$ . Il rapporto fra il numero di molecole di acqua e di acqua ossigenata è perciò 200, e quello tra le molecole di  $\text{H}_2\text{O}_2$  e di  $\text{H}_2\text{O}$  è di 0,005. La frazione di mole di  $\text{H}_2\text{O}_2$  è  $\frac{1}{200+1} = 0,004925$ ; e di  $\text{H}_2\text{O}$  è  $\frac{200}{200+1} = 0,995075$ . La concentrazione in p.f.g. di  $\text{H}_2\text{O}_2$  per 1000 g acqua è  $\frac{1000}{200 \times 18,0154} = 0,2775$ .

La soluzione contiene:  $\frac{34,0154 \times 100}{(200 \times 18,0154) + 34,0154} = 1,935$  per cento in peso di  $\text{H}_2\text{O}_2$ .

## Conversion factors

To convert kJ to:	Multiply by	Log <sub>10</sub> =
Pour convertir kJ en:	Multiplier par	
Um kJ zu verwandeln in:	ist zu multiplizieren mit	
Per convertire i kJ in:	Moltiplicare per	
kg cal <sub>15</sub>	0.23895	1.378304
BTU <sub>59</sub>	0.94823	1.976912
CTU <sub>15</sub>	0.52679	1.721639
l-atm	9.8690	0.994272
kg m	101.972	2.008479
ft. lb.	737.56	2.867798
h.p. hr (elec.)	0.00037236	4.570959
cheval vap. hr	0.00037767	4.577116
kw hr (abs.)	0.00027778	4.443698
volt Faraday (abs.)	0.010363	2.015473
volt amp. sec <sup>-1</sup>	1000	3.000000
quanta sec <sup>-1</sup>	$1.5258 \times 10^{16}$	36.183494

## A-B Table

Formula	State	Q, kJ	Method	Lit.
<b>Oxygen</b>				
$\text{O}_2$	gas	0	Def.	
$\text{O}_{2(\text{II})}$	c		Tr.: 0.701 <sup>-231</sup> <sub>(I)</sub>	(346)
$\text{O}_{2(\text{III})}$	c		Tr.: 0.073 <sup>-250</sup> <sub>(II)</sub>	(346)
$\text{O}_2$	aq.	13.8	13.8*	(426, 1047,* 1050)
	Pt	736	+ Pt <sup>50</sup>	(727)
$\text{O}$	gas	- 341	dissoc.*	(197.5, 347)
$\text{O}_2$	gas	- 144	dissoc.; &	(76, 547, 575, 739, 790*)
	aq.	- 136	8*	(368,* 888*)
$\text{O}_4$	gas	+ 0.5	dissoc.*	(636*)
<b>Hydrogen</b>				
$\text{H}_2$	gas	0	Def.	
	sat.	5.94	5.94	(980,* 1047†)
	in Pt	57.8	+ Pt	(387, 727)
	as $\text{Pd}_2\text{H}$	74.2	+ Pd	(237, 445,* 726)
$\text{H}$	gas	- 211	dissoc.*	(299.5, 313.5, 605, 606, 607,* 641.1,* 915.5, 1063*)
$\text{H}^+$	=	0	Def.	
$\text{OH}^-$ (cf. p. 212)	$\text{C}_2\text{H}_5\text{OH}$ aq.	- 29.0 228.2	$\text{HClC}_2\text{H}_5\text{OH}$ $\text{KOH}$ ; &	(311)

Formula	State	Q, kJ	Method	Lit.
<b>Hydrogen.—(Continued)</b>				
$\text{H}_2\text{O}$	liq.	286.2	$\text{H}_2 + \text{O}_2$ ; &	(2, 16, 100.5, 105, 202, 322, 358.5, 459.5, 704, 890, 916, 970, 971, 976)
	gas	242.0	→liq.	(260, 461, 505,* 509,* 510,* 524,* 864, 865, 926)
$\text{H}_2\text{O}_2$	liq.	186.3	1.9 <sup>15</sup> <sub>200</sub>	(289)
	gas	137.7	→liq.*	(281,* 651, 661.1,* 1066*)
	200	188.2	+ $\text{KMnO}_4$ ; &	(72, 93, 146, 976)
	3.46	187.9	dil.	(389)
	2.53	187.8	dil.	
	1.00	186.9	dil.	

## Fluorine

$\text{F}_2$	gas	0	Def.	
$\text{F}^-$	aq.	327.3	KF	
$\text{HF}(\text{ideal})$	gas	267.8	$\text{H}_2 + \text{F}_2$ ; &	(464, 465, 1032)
$(\text{HF})_{2.5}[\text{HF at 745 mm}]$	gas	958.4	dissoc.*	(923*)
$\text{HF}$	liq.	397	19	(464, 465)
	600	316.8	dil.	(157, 797)
	400	316.2	$(\text{HF}_2)_{48.4}^{18}_{400}$	(167, 1032)
	200	316.2	dil.	(464, 465)
	12	316.2	dil.	
	6.5	315.8	dil.	
	2.2	314.3	dil.	
	1.7	312.8	dil.	
	0.5	307.6	dil.	
$\text{HF}_2^-$	aq.	624.4	$\text{KHF}_2$	
$\text{H}_2\text{F}_2(\text{ideal})$	gas	1774	dissoc.*	(923*)

## Chlorine

$\text{Cl}_2$	gas	0	Def.	
	aq. (ideal)	30	aq.*	(348*)
	$\text{CCl}_4$	19.0	19.0°	(762)
	aq.	22	aq.	(1052*)
$\text{Cl}$	gas	- 120.3	dissoc.*	(507,* 891,* 1032,* 1061,* 1063*)
$\text{Cl}^-$	aq.	165.55	$\text{HCl}$	(599,* 988*)
$\text{Cl}_2 \cdot 7\text{H}_2\text{O}$	c	950	dissoc.*; &	(393, 615,* 988*)
$\text{ClO}^-$	aq.	108	$\text{NaOCl}$	
$\text{ClO}_2$	liq.	- 126	→gas	(582)
	gas	- 98.3	dissoc.	(223, 227, 692*)
	aq.	- 70.7	27.6	(223)
$\text{ClO}_2^-$	aq.	80	$\text{NaClO}_2$	
$\text{ClO}_4^-$	aq.	167	$\text{KClO}_4$	
$\text{Cl}_2\text{O}$	gas	- 76.4	39.5 <sup>18</sup> <sub>800</sub>	(976)
	aq.	- 36.9	= $\text{HClO}$	
$\text{HCl}(\text{I})$	c		Tr.: 1.23 <sup>-174</sup> <sub>(II)</sub>	(348, 1088.5)
$\text{HCl}$	gas	92.2	$\text{H}_2 + \text{Cl}_2$ ; &	(2, 48.1, 486, 976)
(see also p. 212)				(762)
	$\text{CCl}_4$	107.6	15.4°	
	$\text{C}_2\text{H}_5\text{OH}$	136.4	44.4	
	∞	165.55	dil.	(64, 745, 866,*† 976,*† 940,*† 1002,*† 10210†)
	400	165.39	dil.	
	200	165.16	73.0 <sup>18</sup> <sub>200</sub> ; &	(158,* 643,* 760,* 976, 1021,* 1112)
	100	164.81	dil.	
	50	164.23	dil.	



Formula	State	Q, kj	Method	Lit.
<b>Chlorine.—(Continued)</b>				
HCl.—(Continued).....	25	163.21	dil.	
	10	160.3	dil.	
	5	155.3	dil.	
	3	148.6	dil.	
	2	140.2	dil.	
	1	115.2	dil.	
HCl.....	In mixtures			(500,†* 501*†)
HCl.2H <sub>2</sub> O.....	c-18	713	aq.	(83, 882)
HClO.....	200	124.6	+HI; &	(69, 976)
HClO <sub>2</sub> .....	400	80	H <sub>2</sub> SO <sub>4</sub> +	(77, 976)
			BaClO <sub>3</sub>	
HClO <sub>4</sub> .....	liq.	81	85 <sup>19</sup> <sub>600</sub>	(174)
	200	166	+KOH; &	(106, 976)
	96	165.8	dil.	(104)
	42	166.1	dil.	
	9.5	165.5	dil.	
	6	164.3	dil.	
	4.15	163.2	dil.	
	3.08	160.6	dil.	
	2.33	143.7	dil.	
	1.43	134.9	dil.	
	1	117	dil.	
HClO <sub>4</sub> .H <sub>2</sub> O.....	c	420	32	(104)

<b>Bromine</b>				
Br <sub>2</sub> .....	liq.	0	Def.	
	gas	- 32.0	→liq.	(16.5, 168, 836,* 882,* 976)
	c	10.8	→liq.	(228,* 506,* 545,* 548, 846, 1048*)
	sat.	3	3*	(1048*)
	aq. (ideal)	5	5	(126, 811, 976)
Br.....	gas	- 111.7	dissoc.*	(210,* 599,* 788,* 789*)
Br <sup>-</sup> .....	aq.	119.7	HBr	
Br <sub>2</sub> <sup>-</sup> .....	aq.	130	HBr <sub>2</sub>	
Br <sub>3</sub> <sup>-</sup> .....	aq.	149	HBr <sub>3</sub>	
BrO <sub>2</sub> <sup>-</sup> .....	aq.	91	KBrO	
BrO <sub>3</sub> <sup>-</sup> .....	aq.	51	HBrO <sub>3</sub>	
HBr <sub>(I)</sub> .....	c		Tr. 0.692 <sup>-107</sup> <sub>(II)</sub>	(348)
HBr <sub>(II)</sub> .....	c		Tr. 0.473 <sup>-183</sup> <sub>(III)</sub>	(348)
HBr.....	gas	36.2	83.2 <sup>18</sup> <sub>200</sub>	(64, 976)
HBr.....	∞	119.7	extrap.	
	400	119.6	dil.	
	200	119.4	Br <sub>2</sub> + KCl; &	(48.1, 81, 976)
	100	119.3	dil.	(64, 883, 976)
	50	118.9	dil.	
	25	118.3	dil.	
	10	115.9	dil.	
	6	112.4	dil.	
	5	109.7	dil.	
	3	102.6	dil.	
	2	94	extrap.	
HBr.2H <sub>2</sub> O.....	c-18	688	dissoc.; &	(64, 883*)
HBr <sub>2</sub> .....	200	130	Br <sub>2</sub> + HBr; &	(648*)
HBr <sub>3</sub> (?).....	∞	149	Br <sub>2</sub> + Br <sub>(aq.)</sub>	(648*)
HBrO.....	aq.	107	N = HClO	
HBrO <sub>3</sub> .....	200	53	+SnCl <sub>2</sub> ; &	(81, 976)

<b>Iodine</b>				
I.....	c	0	Def.	
I <sub>2</sub> .....	gas	- 63	c*	(34,* 359)
	liq. 114	- 20	→gas*	(34*)
	aq. (ideal)	- 23	- 23*	(502,* 904†)
I.....	gas	- 106.59	dissoc.*	(200, 231, 599,* 641.1,* 927,* 1061*)
I <sup>-</sup> .....	aq.	55.8	HI	
I <sub>3</sub> <sup>-</sup> .....	aq.	91	HI <sub>3</sub>	
IO <sub>3</sub> <sup>-</sup> .....	aq.	227	KIO <sub>3</sub>	(904*)
IO <sub>4</sub> <sup>-</sup> .....	aq.	610	K <sub>2</sub> IO <sub>4</sub>	
IO <sub>3</sub> .....	c	176.0	-7.5 <sup>18</sup> <sub>1500</sub>	(82, 314, 976)
HI <sub>(I)</sub> .....	c		Tr.; 0.526 <sup>-194</sup> <sub>(II)</sub>	(348)
HI <sub>(II)</sub> .....	c		Tr.; 0.295 <sup>-201</sup> <sub>(III)</sub>	(348)

<b>Iodine.—(Continued)</b>				
HI.....	gas	- 21.8	80 5 <sup>18</sup> <sub>200</sub> ; &	(138, 309, 939,* 976)
	∞	55.8	extrap.	
	200	55.7	HCl +	(81, 976)
			PbI <sub>2</sub> ; &	
	100	55.6	dil.	(64, 976)
	50	55.4	dil.	
	20	54.8	dil.	
	10	53.0	dil.	
	5	48.0	dil.	
	3	37	dil.	
	2	28	dil.	
HI <sub>2</sub> .....	aq.	91	I <sub>2</sub> + HI; &	(1034)
HIO.....	aq.	95	N = HClO	
HIO <sub>2</sub> .....	c	236.0	-9.0	(82, 314, 976)
	aq.	227	HI + KIO <sub>3</sub>	(80, 81, 925,* 976)
			= H <sub>2</sub> IO <sub>4</sub>	
HIO <sub>4</sub> .....	aq.	190		
HIO <sub>6</sub> <sup>-</sup> .....	aq.	663		
H <sub>2</sub> IO <sub>6</sub> <sup>-</sup> .....	aq.	716	K <sub>2</sub> H <sub>2</sub> IO <sub>6</sub>	
H <sub>3</sub> IO <sub>6</sub> <sup>-</sup> .....	aq.	761	K <sub>3</sub> H <sub>3</sub> IO <sub>6</sub>	
H <sub>4</sub> IO <sub>6</sub> <sup>-</sup> .....	aq.	729	KH <sub>4</sub> IO <sub>6</sub>	
H <sub>5</sub> IO <sub>6</sub> <sup>-</sup> .....	c	772	-5.8 <sup>18</sup> <sub>2000</sub>	(976)
	aq.	766	+SnCl <sub>2</sub> ; &	(976)
2HIO <sub>3</sub> .I <sub>2</sub> O <sub>5</sub> .....	c	353	-23.9 <sup>12</sup> <sub>1700</sub>	(82)
ICl(α).....	c	28	I + Cl; &	(94)
ICl(β).....	c	27	→(α)	(951, 963)
ICl.....	liq.	19	→(α)	(951, 963, 976)
ICl <sub>3</sub> .....	c	70	I + Cl; &	(94)
IBr.....	liq.	11	I + Br	(94)
	gas	- 40	dissoc.*	(214,* 738*)

<b>Sulfur</b>				
S(rhom.).....	c	0	Def.	
S(monocl.).....	c	- 0.29	Tr.; 0.29	(340,* 642, 702, 956*)
S <sub>λ</sub> .....	liq.	- 1.6	→S(rhom.)	(642)
S <sub>μ</sub> .....	liq.	- 3.3	→S <sub>λ</sub>	(642,* 730)
S <sup>-</sup> .....	gas	- 162	dissoc.*	(641.1*)
S <sub>2</sub> .....	aq.	- 42	Na <sub>2</sub> S	
S <sub>3</sub> .....	gas	- 124	dissoc.*	(641.1*)
S <sub>4</sub> .....	aq.	- 40	Na <sub>2</sub> S <sub>2</sub>	
S <sub>5</sub> .....	aq.	- 33	Na <sub>2</sub> S <sub>3</sub>	
S <sub>6</sub> .....	aq.	- 27	Na <sub>2</sub> S <sub>4</sub>	
S <sub>7</sub> .....	gas	- 95	dissoc.*	(831*)
S <sub>8</sub> .....	gas	- 84	dissoc.*	(831,* 1077)
SO <sub>2</sub> .....	gas	290	S + O <sub>2</sub> ; &	(97, 428.1, 976)
	liq.	315.0	→gas	(265, 344, 345, 672)
	2000	325.8	35.8	(345, 646,*
	1000	324.5	34.4	647,* 942, 976)
	500	323.0	33.0	
	200	321.2	31.2	
	100	319.8	29.8	
	75	319.2	29.2	
SO <sub>3</sub> <sup>-</sup> .....	aq.	468	Na <sub>2</sub> SO <sub>3</sub>	
SO <sub>3</sub> (ice form).....	c	432	156	(52, 450.5, 932*)
	liq.	423	163.9 <sup>20</sup> <sub>1600</sub>	(450.5, 976)
	gas	383	206	(98, 450.5)
	200	582	= H <sub>2</sub> SO <sub>4</sub>	
SO <sub>3</sub> <sup>-</sup> .....	aq.	614.4	K <sub>2</sub> SO <sub>3</sub>	
SO <sub>4</sub> <sup>-</sup> .....	aq.	885.0	K <sub>2</sub> SO <sub>4</sub>	
S <sub>2</sub> O <sub>3</sub> <sup>-</sup> .....	aq.	590	Na <sub>2</sub> S <sub>2</sub> O <sub>3</sub>	
S <sub>2</sub> O <sub>4</sub> <sup>-</sup> .....	aq.	665	Na <sub>2</sub> S <sub>2</sub> O <sub>4</sub>	
S <sub>2</sub> O <sub>5</sub> <sup>-</sup> .....	aq.	948.7	= HSO <sub>3</sub> <sup>-</sup>	
S <sub>2</sub> O <sub>6</sub> <sup>-</sup> .....	aq.	1148	Na <sub>2</sub> S <sub>2</sub> O <sub>6</sub>	
S <sub>2</sub> O <sub>7</sub> <sup>-</sup> .....	c	356(?)	+ aq.	(446)
S <sub>2</sub> O <sub>8</sub> <sup>-</sup> .....	aq.	1296	K <sub>2</sub> S <sub>2</sub> O <sub>8</sub>	
S <sub>2</sub> O <sub>9</sub> <sup>-</sup> .....	aq.	1093	Na <sub>2</sub> S <sub>2</sub> O <sub>9</sub>	



Formula	State	Q, kj	Method	Lit.
<b>Sulfur.—(Continued)</b>				
$S_2O_6^{2-}$	aq.	1096	$Na_2S_4O_6$	
$S_2O_6^{2-}$	aq.	1120	$K_2S_2O_8$	
$HS^-$	aq.	15	KHS	
$H_2S$	gas	22	+I <sub>2</sub> ; &	(641.1, * 823, 976)
	liq.	40	gas	(424*)
	aq.	41.3	19.1; &	(976, 1052*)
$H_2S \cdot 7H_2O$	c <sup>-20</sup>	1670	dissoc.*	(257, * 424, * 897*)
$H_2S_2 + S_2$	liq.	10	+I <sub>2</sub> (aq.)	(897)
$HSO_3^-$	aq.	617.3	$KHSO_3$	
$HSO_4^-$	aq.	878	$KHSO_4$	
$H_2SO_2$	aq.	463	$N = H_2SO_2$	
$H_2SO_3$	200	607.2	$= SO_2(aq.)$	
$H_2SO_4$	liq.	794.1	74.3 <sup>18</sup> <sub>200</sub>	(243)
(see also p. 212)	c	804.5	+ aq.	(56, 243, 498)
	∞	880.0	$= SO_4^{2-}$	
	1599	873.6	dil.	
	799	871.6	dil.	
	399	869.8	dil.	
	199	868.4	$N, Na_2SO_4$ ; &	(50, 53, 843, 976*)
	99	867.8	dil.	(138, † 243, * 358, 458, 672, 748, 803, 812, 890, † 976*)
	49	866.8	dil.	
	19	864.9	dil.	
	9	859.5	dil.	
	8	858.0	dil.	
	7	856.4	dil.	
	6	854.3	dil.	
	5	851.3	dil.	
	4	847.9	dil.	
	3	843.1	dil.	
	2	835.9	dil.	
	1.5	830.9	dil.	
	1.0	822.1	dil.	
	0.5	809.7	dil.	
$H_2SO_4 \cdot H_2O$	liq.	1108.3	aq.	(243)
	c	1127.6	aq.	(57, 243)
$H_2S_2O_8$	1500	580	$Na_2S_2O_8 + HCl$	(976)
$H_2S_2O_4$	aq.	659	$N = H_2S_2O_4$	
$H_2S_2O_6$	400	1148	$N, Na_2S_2O_6$	(745, 976)
$H_2SO_4 \cdot SO_2$	liq.	1230	aq.	(243)
	c	1241.0	→ liq.	(1076)
$H_2S_2O_8$	aq.	1297	+ $FeSO_4$ ; &	(138)
$H_2S_2O_6$	aq.	1096	$N = H_2S_2O_6$	
$H_2S_2O_4$	aq.	1098	$N = H_2S_2O_4$	
$H_2S_2O_3$	aq.	1120	$N = H_2S_2O_3$	
$S_2Cl_2$	gas	23.6	→ liq.	(504, * 770)
	liq.	60	$S + Cl$	(770, 976)
$S_2Cl_4$	liq.	60+	$S_2Cl_2 + Cl_2$	(17, 36)
$SOCl_2$	gas	174	→ liq.	(770)
	liq.	201	164 KOH	(770, 771)
$SO_2Cl_2$	gas	338	→ liq.	(771, 1109)
	liq.	367	263 <sub>100</sub>	(770, 771, 976)
$S_2O_3Cl_2$	liq.	677	+ KOH	(770, 771)
	gas	623	→ liq.	(770, 771)
$SO_2 \cdot HCl$	liq.	583	$SO_2 + HCl$	(772)
$S_2Br_2$	liq.	8.4	$S + Br$	(770, 798)
$S_2I_2$ (?)	c	0.0	$S + I$	(770)

## Selenium

$Se$ (γ) (insoluble)	c	0	Def.	
$Se$ (α) (soluble)*	amorp.	- 6.0	+ $Cl_2$ ; &	(730.1, 798)
$Se$ (β) (soluble)*	c	- 1.6	+ $Cl_2$ ; &	(730.1, 798)
$Se$ (rapidly cooled)	gls.	- 4	+ $Cl_2$ ; &	(798)
$Se_2$	gas	146	$Se_2$	(817)
$Se^-$	aq.	- 112	$Na_2Se$	
$SeO_2$	c	236.1	- 3.8	(549, 976)
	aq.	232	$SeCl_4 + H_2O$ ; &	(976)
$SeO_3^{2-}$	aq.	515	$Na_2SeO_3$	
$SeO_4^{2-}$	aq.	613	$Na_2SeO_4$	
$HSe^-$	aq.	- 154	KHSe	

Formula	State	Q, kj	Method	Lit.
<b>Selenium.—(Continued)</b>				
$H_2Se$	gas	- 66	+ I <sub>2</sub> ; &	(308, * 350, 785.5, * 878*)
	aq.	- 56.1	10 <sup>18</sup>	(350, 424, * 878, * 1101)
$H_2Se + XH_2O$	c	4 + $XH_2O$	dissoc.*	(424*)
$HSeO_3^-$	aq.	522	$NaHSeO_3$	
$HSeO_4^-$	aq.	604	$NaHSeO_4$	
$H_2SeO_3$	c	535.8	- 17.2	(549)
	aq.	518.6	$= SeO_2(aq.)$	
$H_2SeO_4$	liq.	530	70 <sub>400</sub>	(696)
	c	545	55.9 <sub>400</sub>	(696)
	200	600	dil. = $H_2SO_4$	
	1000	603	$SeO_2 + HClO_4$ ; &	(976)
$H_2SeO_4 \cdot H_2O$	c	856	31.2 <sub>400</sub>	(696)
	liq.	837	51 <sub>400</sub>	(696)
$Se_2Cl_2$	liq.	92.7	$Se + Cl_2$	(976)
$SeCl_4$	c	193.2	$Se + Cl_2$	(976)
$SeO_2 \cdot SO_2$	c	683	134.4 <sup>15</sup> <sub>4000</sub>	(896)

## Tellurium

$Te$ (metallic)	c	0	Def.	
$Te$ (amorphous)	amorp.	- 11.4	+ $Br_2$	(302, 381, 918)
$TeO_2$	c	327.7	$Te + 2H_2O^*$	(711, 918)
	aq.	320	$TeCl_4 + H_2O$	(976)
$TeO_2 \cdot H_2O$	c	606	0	(976)
$TeO_3$	c	348	+ $Na_2O$	(711)
$TeO_3^-$	aq.	580	$K_2TeO_3$	
$TeO_4^-$	aq.	722	$K_2TeO_4$	
$H_2Te$	gas	- 142	+ $FeCl_3$ ; &	(381)
$H_2TeO_4$	aq.	708	$TeO_2 + Br_2$ ; &	(381, 976)
$H_2TeO_4 \cdot 2H_2O$	c	1294	- 14.0 <sup>14</sup> <sub>600</sub>	(696)
$TeCl_4$	c	324	$Te + Cl_2$	(976)
$TeBr_4$	$Br_2$	278	$Te + Br_2$	(381)
$2TeO_2 \cdot SO_2$	c	1280	257 <sup>15</sup> <sub>KOH</sub>	(896)

## Nitrogen

$N_2$	gas	0	Def.	
$N$	gas	- 540	dissoc.*	(197.5)
$N_2(1)$	c	- 237.6	Tr.; 0.22 <sup>11</sup> <sub>(II)</sub>	(346)
$N_3^-$	aq.	- 245	$BaNa_3$	
$NO$	gas	- 90	$NO + C_2N_2$ ; &	(71, 90, 755, * 976)
	gas	- 71	+ $CO$ ; &	(80, 954, 976)
	liq.	- 78.4	→ gas	(672)
$N_2O \cdot 6H_2O$	c <sup>0</sup>	1692	dissoc.*	(1016*)
$NO_2$	gas (ideal)	- 31.1	$NO + O^*$ ; &	(312, * 641.10)
$NO_2^-$	aq.	107	$NaNO_2$	
$NO_3^-$	aq.	208.4	$HNO_3$	
$N_2O_2^-$	aq.	- 15	$Na_2N_2O_2$	
$N_2O_4$	gas (ideal)	- 7.8	dissoc.; &	(71, 209, * 911, * 1068*)
	liq.	21	+ $Cl_2$ ; &	(71, 994.5)
	c <sup>-10</sup>	33.6	→ liq.	(835)
$N_2O_5$	gas	5	124.7 <sup>10*</sup>	(55, 303*)
	c	61	69.8 <sup>10</sup> <sub>400</sub>	(55)
$NH_3$	gas	45.8	dissoc.; &	(485, 486, 487, * 488, 955)
(see also p. 213)				
	liq.	66.3	→ gas	(733, 848, 952)
	200	81.3	35.4 <sup>18</sup> <sub>200</sub>	(33, 66, 359, 976, 1021)
	50	81.2	dil.	(66, 976)
	25	81.1	dil.	
	15	81.0	dil.	
	3.2	79.7	dil.	
	1.0	75.9	dil.	
$NH_4^+$	aq.	132.7	$NH_4Cl$	
$N_2H_4$	aq.	- 13.6	$N_2H_4 \cdot H_2SO_4$	(21, 1094)
			+ $Ba(OH)_2$	
$N_2H_5H^+$	aq.	27	$N_2H_5HCl$	
$N_2H_6H^{++}$	aq.	27	$N_2H_6 \cdot 2HCl$	
$HN_3$	aq.	- 228	N	(163)
$NH_2 \cdot HN_2$	c	- 84	dissoc.	(163)
	aq.	- 113	- 28.2 <sup>17</sup> <sub>600</sub>	(21, 163)



Formula	State	Q, kJ	Method	Lit.
<b>Nitrogen.—(Continued)</b>				
HNO <sub>2</sub> .....	200	121	NaNO <sub>2</sub> + HCl	(71, 954)
HNO <sub>2</sub> .....	gas	147.9	liq.	(85)
	liq.	177.3	30.0 <sup>10</sup>	(85)
	∞	208.4	extrap.	
	400	208.41	→dil.	
	200	208.87	HNO <sub>2</sub> + Cl <sub>2</sub> ;	(71)
			&	
	100	208.43	dil.	(62, 867, <sup>o</sup>
	50	208.52	dil.	976)
	25	208.67	dil.	
	20	208.5	dil.	
	10	207.9	dil.	
	5	205.2	dil.	
	3	201.2	dil.	
	2	197.3	dil.	
	1	191.0	dil.	
	0	177.3	dil.	
NH <sub>2</sub> OH.....	aq.	87	NH <sub>2</sub> OH + HCl; &	(79, 330, 976)
NH <sub>2</sub> OH.....	200	367.5	= NH <sub>2</sub> aq.	
NH <sub>2</sub> OH.H <sup>+</sup> .....	aq.	126	NH <sub>2</sub> OH.HCl	
NH <sub>2</sub> NO <sub>2</sub> .....	c	280.1	-19.9 <sup>12</sup> <sub>400</sub> ; &	(71, 976)
	400	240.8	N	(71, 976)
NH <sub>2</sub> NO <sub>2</sub> (v).....	c	368.0	-26.5 <sup>18</sup> <sub>200</sub>	(64, 459, 729, <sup>o</sup>
				976, 981, <sup>o</sup>
				1046 <sup>o</sup> )
NH <sub>2</sub> NO <sub>2</sub> (v).....	c		Tr.; -0.5 <sup>-18</sup> <sub>(IV)</sub>	(19, 45.4,
				234, <sup>+</sup> 286
				729)
NH <sub>2</sub> NO <sub>2</sub> (II).....	c		Tr.; 1.67 <sup>32</sup> <sub>(IV)</sub>	(45.1, 234, <sup>+</sup>
				729, 1083.5)
NH <sub>2</sub> NO <sub>2</sub> (II).....	c		Tr.; 1.3 <sup>82</sup> <sub>(III)</sub>	(45.1, 234 <sup>+</sup> )
NH <sub>2</sub> NO <sub>2</sub> (I).....	c		Tr.; 4.3 <sup>125</sup> <sub>(II)</sub>	(45.1, 234 <sup>+</sup> )
(see also p. 162)	∞	340.9	extrap.	
	1000	341.05	dil.	
	500	341.16	dil.	
	200	341.58	N	(79, 976)
	100	342.01	dil.	(286, 328, <sup>+</sup>
	50	342.97	dil.	829, <sup>o</sup> 729,
	25	344.70	dil.	827, <sup>o</sup> 976,
	20	345.0	dil.	981 <sup>o</sup> )
	10	346.8	dil.	
	5	349.4	dil.	
	3	350.7	dil.	
	2.5	352.4	dil.	
NH <sub>2</sub> OH.HNO <sub>2</sub> .....	c	350	+O <sub>2</sub>	(181)
	aq.	334	-25 <sup>12</sup> <sub>200</sub>	(181)
H <sub>2</sub> N <sub>2</sub> O <sub>2</sub> .....	aq.	35	Na <sub>2</sub> N <sub>2</sub> O <sub>2</sub>	(133)
N <sub>2</sub> H <sub>2</sub> HOH.....	c	284.7	8.0 <sup>18</sup> <sub>400</sub>	(21)
	aq.	272.7	= N <sub>2</sub> H <sub>2</sub> aq.	
N <sub>2</sub> H <sub>2</sub> .HNO <sub>2</sub> .....	aq.	235.7	N	(21)
N <sub>2</sub> H <sub>2</sub> .2HNO <sub>2</sub> .....	aq.	443.9	N	(21)
NH <sub>2</sub> F.....	c	467.5	-6.3	(464)
	aq.	461.2	N	(464, 465,
				976)
NCl <sub>3</sub> .....	CCl <sub>4</sub>	-229.5	+HCl; &	(762, 992)
NOCl.....	gas	-53.0	+KOH; &	(238, 641.1, <sup>+</sup>
				982, <sup>+</sup> 986, <sup>+</sup>
				989, <sup>+</sup> 990, <sup>+</sup>
				992, <sup>+</sup>
				1005.1 <sup>+</sup> )
NH <sub>2</sub> Cl(I).....	c		Tr.; 4.2 <sup>184</sup> <sub>(II)</sub>	(238, <sup>+</sup> 992, <sup>+</sup>
				1027 <sup>+</sup> )
NH <sub>2</sub> Cl(II).....	c	314.2	-16.3 <sup>18</sup> <sub>200</sub> ; &	(9, 49, 54,
				298, <sup>+</sup> 313, <sup>+</sup>
				623, <sup>+</sup> 729,
				824, 890, <sup>+</sup>
				924, <sup>+</sup> 976,
				1046 <sup>o</sup> )
NH <sub>2</sub> Cl(III).....	c		Tr.; -1.5 <sup>-81</sup> <sub>(II)</sub>	(349, 922)
NH <sub>2</sub> Cl.....	∞	298.3	dil.	
(see also p. 161)	1000	298.13	dil.	
	500	298.04	dil.	

Formula	State	Q, kJ	Method	Lit.
<b>Nitrogen.—(Continued)</b>				
NH <sub>2</sub> Cl—(Continued)....	200	297.90	N	(49, 50, 976 <sup>o</sup> )
	100	297.84	dil.	(652, <sup>+</sup> 827, <sup>o</sup>
	50	297.88	dil.	976)
	25	298.08	dil.	
	10	300.2	dil.	
N <sub>2</sub> H <sub>4</sub> .HCl.....	c	214.7	-22.8 <sup>17</sup> <sub>500</sub>	(21)
	aq.	192.0	N; &	(21)
N <sub>2</sub> H <sub>4</sub> .2HCl.....	c	383.0	-25.9 <sup>19</sup> <sub>500</sub>	(21)
	aq.	357.0	BaCl <sub>2</sub> +	(21, 163)
			N <sub>2</sub> H <sub>4</sub> SO <sub>4</sub> ; &	
			analogy	
NH <sub>2</sub> Cl.3NH <sub>2</sub> .....	c	560	dissoc. <sup>+</sup>	(228, 994 <sup>+</sup> )
NH <sub>2</sub> Cl.6NH <sub>2</sub> .....	c	805		(79)
NH <sub>2</sub> OH.HCl.....	c	304.5	-13.8 <sup>24</sup> <sub>450</sub>	(79, 330, 976)
	400	290.6	N	(104)
NH <sub>2</sub> ClO <sub>4</sub> .....	c	327.7	-26.6 <sup>20</sup> <sub>220</sub>	(104)
	aq.	301	N	(104)
NOBr.....	gas	-73.4	→gas	(987 <sup>+</sup> )
	liq.	-47	+KOH; &	(987 <sup>+</sup> )
NOBr <sub>2</sub> .....	gas	-20	→liq.	(987 <sup>+</sup> )
	liq.	+7	+KOH; &	(987 <sup>+</sup> )
NH <sub>2</sub> Br(II).....	c	270.8	-18.6 <sup>18</sup> <sub>200</sub>	(11, 862, <sup>+</sup>
				929, <sup>+</sup> 976)
NH <sub>2</sub> Br(I).....	c		Tr.; 3.2 <sup>138</sup> <sub>(II)</sub>	(238 <sup>+</sup> )
	200	252.2	N	N = HCl
			Tr.; 2.9 <sup>-18</sup> <sub>(II)</sub>	(238 <sup>+</sup> )
NH <sub>2</sub> I(I).....	c		-14.9 <sup>18</sup> <sub>200</sub>	(976)
NH <sub>2</sub> I(II).....	c	203.2	N	
	200	188.3	N	
NS.....	c	-133	dissoc.	(174)
N <sub>2</sub> O <sub>2</sub> (SO <sub>2</sub> ) <sub>2</sub> .....	c	948	477 <sup>22</sup>	(1110)
NH <sub>2</sub> HS.....	c	163	KOH(300)	(66, 237, 841, <sup>+</sup>
			-14	842, <sup>+</sup> 858, <sup>+</sup>
				1028 <sup>+</sup> )
	aq.	149.3	NH <sub>2</sub> +	(56, 976)
			(NH <sub>2</sub> ) <sub>2</sub> S	
(NH <sub>2</sub> ) <sub>2</sub> S.....	200	231.2	N	(56, 976)
NH <sub>2</sub> S <sub>2</sub> .....	c	135	+I <sub>2</sub>	(897)
	aq.	117	-18 <sup>12</sup> <sub>150</sub>	(897)
NH <sub>2</sub> S <sub>3</sub> .....	c	133	+I <sub>2</sub>	(897)
	aq.	115	-18	(897)
(NH <sub>2</sub> ) <sub>2</sub> S <sub>3</sub> .....	c	271	+I <sub>2</sub>	(897)
	aq.	235	-36 <sup>12</sup> <sub>1000</sub>	(897)
NH <sub>2</sub> HSO <sub>3</sub> .....	aq.	750	= (NH <sub>2</sub> ) <sub>2</sub> S <sub>2</sub> O <sub>3</sub>	(378)
NH <sub>2</sub> HSO <sub>4</sub> .....	c	1006.2	-0.1 <sup>18</sup> <sub>200</sub>	(976)
	800	1008.5	dil.	
	400	1007.2	(NH <sub>2</sub> ) <sub>2</sub> SO <sub>4</sub> +	(56, 976)
			H <sub>2</sub> SO <sub>4</sub>	
	200	1006.1	dil.	(976)
	100	1005.3	dil.	
	50	1004.8	dil.	
	20	1004.3	dil.	
	10	1002.8	dil.	
NH <sub>2</sub> OH.H <sub>2</sub> SO <sub>4</sub> .....	aq.	1001	N	(79, 330)
N <sub>2</sub> H <sub>4</sub> .H <sub>2</sub> SO <sub>4</sub> .....	c	939	+O <sub>2</sub>	(79)
	aq.	903	-35.7 <sup>19</sup> <sub>1200</sub>	(21)
(NH <sub>2</sub> ) <sub>2</sub> SO <sub>3</sub> .....	c	879.7	-6.4 <sup>18</sup> <sub>440</sub>	(378)
	aq.	873.4	N	(378)
(NH <sub>2</sub> ) <sub>2</sub> SO <sub>3</sub> .H <sub>2</sub> O.....	c	1178	-18.2 <sup>12</sup>	(378, 802)
(NH <sub>2</sub> ) <sub>2</sub> SO <sub>4</sub> .....	c	1162.0	-10.0 <sup>18</sup> <sub>200</sub>	(976)
	400	1152.1	N	(56, 224, 976 <sup>+</sup> )
	200	1152.4	dil.	(976)
	100	1152.9	dil.	
	50	1153.7	dil.	
	30	1154.5	dil.	
	10	1155.6	dil.	
(NH <sub>2</sub> OH) <sub>2</sub> .H <sub>2</sub> SO <sub>4</sub> .....	c	1158	-24.3 <sup>12</sup> <sub>900</sub>	(79)
	aq.	1133	N	
(NH <sub>2</sub> ) <sub>2</sub> S <sub>2</sub> O <sub>6</sub> .....	c	1240	-26 <sup>8</sup> <sub>440</sub>	(378)
	aq.	1314	N	(378)
(NH <sub>2</sub> ) <sub>2</sub> S <sub>2</sub> O <sub>8</sub> .....	c	1602	-38 <sup>18</sup> <sub>1000</sub>	(1380)
	aq.	1563	N	(1380)
NSe.....	c	-177	dissoc.	(178)
NH <sub>2</sub> HSe.....	c	102	-21 <sup>18</sup> <sub>1500</sub>	(350)
	aq.	82	N	(350)
(NH <sub>2</sub> ) <sub>2</sub> Se.....	aq.	163	N	(350)



Formula	State	Q, kj	Method	Lit.
<b>Phosphorus<sup>a</sup></b>				
P <sub>2</sub> (white)	c	0	Def.	
P <sub>2</sub> (red)	c	18	+Br <sub>2</sub> ; &	(354, 447, 995*)
P <sub>2</sub>	CS <sub>2</sub>	- 3.8	- 3.8CS <sub>2</sub>	(768)
PO <sub>3</sub> <sup>-</sup>	aq.	984	NaPO <sub>3</sub>	
PO <sub>4</sub> <sup>-</sup>		1250	Na <sub>2</sub> PO <sub>4</sub>	
P <sub>2</sub> O <sub>5</sub>	c	1531	P + O <sub>2</sub>	(447)
	amorp.	1535.4	→c	(308, 447)
	gls.	1555.1	→c	(447)
P <sub>2</sub> O <sub>7</sub> <sup>-</sup>	aq.	2246	Na <sub>4</sub> P <sub>2</sub> O <sub>7</sub>	
P <sub>2</sub> H	c	50	+Br <sub>2</sub>	(628, 768)
PH <sub>3</sub>	gas	- 25	+O <sub>2</sub> ; &	(628, 768)
HPO <sub>3</sub>	c	941.2	40.8	(447)
	aq.	981.4	+H <sub>2</sub> O	(447)
HPO <sub>3</sub> <sup>-</sup>	aq.	961	Na <sub>2</sub> HPO <sub>3</sub>	
HPO <sub>4</sub> <sup>-</sup>	aq.	1287	Na <sub>2</sub> HPO <sub>4</sub>	
H <sub>2</sub> PO <sub>2</sub> <sup>-</sup>	aq.	596	NaH <sub>2</sub> PO <sub>2</sub>	
H <sub>2</sub> PO <sub>3</sub> <sup>-</sup>	aq.	962	NaH <sub>2</sub> PO <sub>3</sub>	
H <sub>2</sub> PO <sub>4</sub> <sup>-</sup>	aq.	1285	NaH <sub>2</sub> PO <sub>4</sub>	
H <sub>3</sub> PO <sub>2</sub>	liq.	581.8	9.1 <sup>19</sup> <sub>150</sub>	(976)
	c	591.6	-0.7 <sup>12</sup> <sub>150</sub>	(976)
	450	591.8	dil.	
	250	590.9	BaH <sub>4</sub> P <sub>2</sub> O <sub>4</sub> + H <sub>2</sub> SO <sub>4</sub>	(976)
	220	590.8	dil.	(797)
	110	588.8	dil.	
	55	587.8	dil.	
H <sub>3</sub> PO <sub>3</sub>	liq.	945.2	12.3 <sup>19</sup> <sub>150</sub>	(976)
	c	938.1	0.5 <sup>19</sup> <sub>150</sub>	(976)
	aq.	957	+Br <sub>2</sub>	(976)
H <sub>3</sub> PO <sub>4</sub>	liq.	1258.6	22.4 <sup>20</sup> <sub>200</sub>	(976)
	c	1268.6	11.3 <sup>19</sup> <sub>150</sub>	(566, 976)
	400	1281.3	dil.	
	200	1281.0	P <sub>2</sub> O <sub>5</sub> + aq.	(447, 976)
	100	1280.7	dil.	(566, 797, 890, 976)
	50	1280.3	dil.	
	20	1279.3	dil.	
	9	1277.5	dil.	
	3	1272.4	dil.	
	1	1265.9	dil.	
H <sub>3</sub> PO <sub>4</sub> ·H <sub>2</sub> O	liq.	1439.6	15.8	(566)
HP <sub>2</sub> O <sub>7</sub> <sup>-</sup>	aq.	2260	Na <sub>2</sub> HP <sub>2</sub> O <sub>7</sub>	
	c	1424.7	0.6	
H <sub>2</sub> P <sub>2</sub> O <sub>5</sub> <sup>-</sup>	aq.	1608	Na <sub>2</sub> H <sub>2</sub> P <sub>2</sub> O <sub>5</sub>	
H <sub>2</sub> P <sub>2</sub> O <sub>7</sub> <sup>-</sup>	aq.	2261	Na <sub>2</sub> H <sub>2</sub> P <sub>2</sub> O <sub>7</sub>	
H <sub>2</sub> P <sub>2</sub> O <sub>7</sub> <sup>-</sup>	aq.	2260	NaH <sub>2</sub> P <sub>2</sub> O <sub>7</sub>	
H <sub>2</sub> P <sub>2</sub> O <sub>5</sub>	aq.	1608	N	(8)
H <sub>2</sub> P <sub>2</sub> O <sub>6</sub>	c	- 31.4 + Q	31.4 <sup>11</sup> <sub>250</sub>	(567)
H <sub>2</sub> P <sub>2</sub> O <sub>6</sub> ·2H <sub>2</sub> O	c	581.5 + Q	-2.2 <sup>10</sup> <sub>250</sub>	(567)
	liq.	545 + Q	→c	(567)
H <sub>2</sub> P <sub>2</sub> O <sub>7</sub>	liq.	2215.4	42.8	(447)
	c	2224.9	33.5	(447)
	aq.	2258.1	+H <sub>2</sub> SO <sub>4</sub> ; &	(447)
H <sub>2</sub> P <sub>2</sub> O <sub>7</sub> ·1½H <sub>2</sub> O	liq.	2655	31.9	(449, 450)
	c	2668	18.8	(449, 450)
PCl <sub>3</sub>	gas	293	→liq.	(14, 847)
	liq.	322	272.6 <sup>19</sup> <sub>1000</sub>	(159, 976)
PCl <sub>5</sub>	c	446	516.6 <sup>22</sup> <sub>1000</sub>	(2, 15, 976)
POCl <sub>3</sub>	liq.	615.8	302.1 <sup>20</sup> <sub>1000</sub>	(159, 976)
PH <sub>3</sub> ·HCl	c	136	HCl + PH <sub>3</sub>	(237)
PBr <sub>3</sub>	liq.	190	+H <sub>2</sub> O; &	(159, 237, 447)
PBr <sub>5</sub>	c	254	P + Br	(769)
POBr <sub>3</sub>	c	447	+H <sub>2</sub> O	(769)
PH <sub>3</sub> ·HBr	c	107	-12.7	(767, 768)
PI <sub>3</sub>	c	46	P + I	(769)
	CS <sub>2</sub>	59	14CS <sub>2</sub>	(769)
P <sub>2</sub> I <sub>4</sub>	c	83	+H <sub>2</sub> O	(769)
PH <sub>3</sub> ·HI	c	50.5	-20	(767, 768)

<sup>a</sup> Heat of mixing H<sub>3</sub>PO<sub>4</sub> + HPO<sub>3</sub> (2°); P<sub>4</sub> = P<sub>2</sub> (g) (939, 943); PF<sub>3</sub> + KOH: ΔQ = 450.7 (forms a fluorophosphoric acid) (125).

Formula	State	Q, kj	Method	Lit.
<b>Phosphorus.—(Continued)</b>				
P <sub>2</sub> N <sub>5</sub>	c	314	+O <sub>2</sub>	(945)
NH <sub>4</sub> H <sub>2</sub> PO <sub>4</sub>	aq.	1419	N	(162)
(NH <sub>4</sub> ) <sub>2</sub> HPO <sub>4</sub>				
= (NH <sub>4</sub> ) <sub>2</sub> H > PO <sub>4</sub>	aq.	1553	N	(162)
(NH <sub>4</sub> ) <sub>2</sub> HPO <sub>4</sub> β				
= (NH <sub>4</sub> ) <sub>2</sub> (HPO <sub>4</sub> )	aq.	1540	N	(162)
(NH <sub>4</sub> ) <sub>2</sub> PO <sub>4</sub>	aq.	1664	N	(162)
<b>Arsenic</b>				
As	c	0	Def.	
As(black)	amorp.	0	+Cl <sub>2</sub>	(521, 798)
As(brown)	amorp.	- 15	+Cl <sub>2</sub>	(177, 798)
AsO <sub>4</sub> <sup>-</sup>	aq.	874	Na <sub>2</sub> AsO <sub>4</sub>	
As <sub>2</sub> O <sub>3</sub> (opaque)	c	654	-31.5 <sup>18</sup> <sub>100</sub> NaOH(100)	(976)
As <sub>2</sub> O <sub>3</sub> (monoclinic)	c	619	→As <sub>2</sub> O <sub>3</sub> (octa)	(896, 10439)
As <sub>2</sub> O <sub>3</sub> (octahedral)	c	645	H <sub>2</sub> + As <sub>2</sub> O <sub>3</sub> *	(914*)
	aq.	622	AsCl <sub>3</sub> + H <sub>2</sub> O; &	(48.1, 976)
As <sub>2</sub> O <sub>5</sub>	c	911.9	25.1	(710, 976)
	aq.	937	As + Br + H <sub>2</sub> O; &	(155, 976)
As <sub>4</sub> O <sub>6</sub>	gas	1121	→As <sub>2</sub> O <sub>3</sub> (mono)	(896, 925.1, 941.1, 1043*)
AsH <sub>3</sub>	gas	- 182	+Br <sub>2</sub>	(766, 768)
AsH <sub>3</sub> ·6H <sub>2</sub> O	c-10	1535	dissoc.*	(420*)
HAsO <sub>3</sub> <sup>-</sup>	aq.	656	Na <sub>2</sub> HAsO <sub>3</sub>	
HAsO <sub>4</sub> <sup>-</sup>	aq.	897	Na <sub>2</sub> HAsO <sub>4</sub>	
H <sub>2</sub> AsO <sub>3</sub> <sup>-</sup>	aq.	711	NaH <sub>2</sub> AsO <sub>3</sub>	
H <sub>2</sub> AsO <sub>4</sub> <sup>-</sup>	aq.	902	NaH <sub>2</sub> AsO <sub>4</sub>	
H <sub>3</sub> AsO <sub>3</sub>	aq.	740	= As <sub>2</sub> O <sub>3</sub> aq.	
H <sub>3</sub> AsO <sub>4</sub>	c	899.7	-1.7 <sup>18</sup> <sub>300</sub> ; &	(976)
AsCl <sub>3</sub>	aq.	898	= As <sub>2</sub> O <sub>3</sub> aq.	
	c	303	As + Cl <sub>2</sub> ; &	(84, 798, 976)
	liq.	182.0	→c <sup>22</sup>	(984)
AsBr <sub>3</sub>	c	194	250 <sup>9</sup> KOH	(84)
	liq.	182	→c	(983)
AsI <sub>3</sub>	c	60	193 <sup>9</sup> KOH	(84)
As <sub>2</sub> S <sub>3</sub>	c	86	+H <sub>2</sub> *	(553*)
<b>Antimony</b>				
Sb(I)	c		Tr.; 0.2 <sup>630</sup> <sub>(11)</sub>	(610)
Sb(II)	c	0	Def.	
Sb(explorative)	c	- 9.9	+Br <sub>2</sub> ; &	(288)
SbO <sub>4</sub> <sup>-</sup>	aq.	883	Na <sub>2</sub> SbO <sub>4</sub>	
Sb <sub>2</sub> O <sub>3</sub> (prism)	c	602	42HF(100)	(464, 465, 710)
Sb <sub>2</sub> O <sub>3</sub> (ordinary)	c	692	42HF(100)	(323, 465)
Sb <sub>2</sub> O <sub>3</sub> (octahedral)	c	697	Na <sub>2</sub> O <sub>2</sub> ; &	(465, 710)
	aq.	537	= H <sub>2</sub> SbO <sub>3</sub>	
Sb <sub>2</sub> O <sub>4</sub>	c	884	+Na <sub>2</sub> O <sub>2</sub>	(710)
Sb <sub>2</sub> O <sub>5</sub>	c	966	+Na <sub>2</sub> O <sub>2</sub>	(710)
	aq.	954.0	= H <sub>2</sub> SbO <sub>4</sub>	
SbH <sub>3</sub>	gas	- 145.7	dissoc.; &	(170, 946)
H <sub>2</sub> SbO <sub>3</sub>	aq.	698	SbCl <sub>3</sub> + H <sub>2</sub> O; &	(464, 976)
H <sub>2</sub> SbO <sub>4</sub>	aq.	906.3	SbCl <sub>3</sub> + H <sub>2</sub> O; &	(976)
SbF <sub>3</sub>	c	906	-7 <sup>100</sup>	(464, 465)
	aq.	899	Sb <sub>2</sub> O <sub>3</sub> + HF	(464, 465)
H <sub>2</sub> SbF <sub>6</sub>	aq.	1856.0	SbF <sub>5</sub> + HF	(464, 465)
SbCl <sub>3</sub>	c	382.5	Sb + Cl <sub>2</sub>	(464, 976)
	liq.	369.5	→c	(982, 984)
	c	449.1	→liq.*; &	(38, 722)
SbCl <sub>5</sub>	liq.	438.9	SbCl <sub>3</sub> + Cl <sub>2</sub> ; &	(464, 976)
	gas	392.6	→liq.	(232)
SbOCl	c	373.3	+HF	(464, 465)
Sb <sub>2</sub> O <sub>5</sub> Cl	c	1448	+HF	(464, 465)
SbBr <sub>3</sub>	c	257	+HF	(170, 466)
	liq.	243.9	→c	(984)
	CS <sub>2</sub>	242	15 <sup>25</sup> CS <sub>2</sub>	(388)
SbI <sub>3</sub>	c	185	+HF	(466)
Sb <sub>2</sub> S <sub>3</sub> (orange)	c	149	+Na <sub>2</sub> S; &	(127)



Formula	State	Q, kj	Method	Lit.
<b>Antimony.—(Continued)</b>				
Sb <sub>2</sub> S <sub>3</sub> (black)	c	150	+Na <sub>2</sub> S; &	(127, 463, 553,* 786*)
Sb <sub>2</sub> S <sub>3</sub> (lilac)	(?)	132	+Na <sub>2</sub> S; &	(127, 463)
Sb <sub>2</sub> S <sub>3</sub> (brown)	(?)	155	+Na <sub>2</sub> S; &	(127, 463)
<b>Bismuth</b>				
Bi	c	0	Def.	
Bi <sub>2</sub> O <sub>3</sub>	c	567	+Na <sub>2</sub> O <sub>2</sub>	(710)
Bi <sub>2</sub> O <sub>3</sub> .XH <sub>2</sub> O	ppt.	572+ X286	BiCl <sub>3</sub> + NaOH; &	(976)
H <sub>2</sub> BiO <sub>3</sub>	aq.	716	= Bi <sub>2</sub> O <sub>3</sub> .XH <sub>2</sub> O	
BiCl <sub>3</sub>	c	379.2	Bi + Cl <sub>2</sub>	(976)
BiOCl	c	367	BiCl <sub>3</sub> + H <sub>2</sub> O	(759,* 976)
Bi <sub>2</sub> S <sub>3</sub>	c		dissoc.*	(553,* 786*)
<b>Carbon<sup>a</sup></b>				
C( $\beta$ graph.)	c	0	Def.	
C(ordinary graphite)	gas	- 638	c	(586, 587, 588)
C( $\alpha$ graph.) (low temp.)	c	1.0	+O <sub>2</sub>	(886, 887)
C(diamond)	c	- 0.7	+O <sub>2</sub>	(885, 886, 887)
C(acetylene)	amorp.	- 2.0	+O <sub>2</sub> ; &	(705)
C(gas carbon)	amorp.	- 2	+O <sub>2</sub>	(885)
C(charcoal) (H-free)	amorp.	- 2	+O <sub>2</sub>	(885)
C(sugar)	amorp.	- 10	+O <sub>2</sub>	(705)
CO(I)	c		Tr.; 0.60 <sup>-212.7</sup> <sub>(II)</sub>	(346)
CO	gas	110.6	+O <sub>2</sub> ; &	(81, 90, 322, 551,* 906,* 976, 1102*)
	sat.	125.0	14.4*	(1049*)
CO <sub>2</sub>	gas	395.0	C + O <sub>2</sub>	(308, 885, 886, 887)
	sat.	414.9	19.9 <sup>-</sup>	(3, 53, 218,* 976)
CO <sub>2</sub> (on charcoal)		426	CO <sub>2</sub> + C	(654)
CO <sub>2</sub> .6H <sub>2</sub> O	c <sup>-10</sup>	1779	dissoc.*	(1016*)
CO <sub>3</sub> <sup>-</sup>	aq.	674	Na <sub>2</sub> CO <sub>3</sub>	(958*)
C <sub>2</sub> O <sub>4</sub> <sup>-</sup>	aq.	816.9	K <sub>2</sub> C <sub>2</sub> O <sub>4</sub>	
CH <sub>4</sub>	gas	80	+O <sub>2</sub>	(165, 976)
C <sub>2</sub> H <sub>2</sub>	gas	- 227.4	+O <sub>2</sub> ; &	(705)
	aq.	- 210	17; &	(153, 1016, 1053*)
C <sub>2</sub> H <sub>2</sub> .6H <sub>2</sub> O	c <sup>0</sup>	981	dissoc.	(1015*)
C <sub>2</sub> H <sub>4</sub>	gas	- 40	+O <sub>2</sub>	(709, 976)
C <sub>2</sub> H <sub>6</sub>	gas	98	+O <sub>2</sub>	(165, 976)
HCO <sub>2</sub> <sup>-</sup>	aq.	414	NaHCO <sub>2</sub>	
HCO <sub>3</sub> <sup>-</sup>	aq.	689.1	dissoc.*; &	(578*)
HCHO <sub>2</sub>	c	426	-9.8 <sup>7</sup> <sub>300</sub>	(56, 800, 957)
	liq.	415.2	+O <sub>2</sub> ; &	(164, 976)
	gas	394.0	→liq.	(250.5, 358.1)
	200	415.8	0.7 <sup>18</sup> <sub>100</sub>	(68, 352, 976)
	100	415.8	dil.	
	50	415.7	dil.	
	2	415.9	dil.	
	1	415.9	dil.	
	0.5	415.6	dil.	
H <sub>2</sub> CO <sub>3</sub>	aq.	701.1	= CO <sub>2</sub> aq.	
CH <sub>3</sub> OH(I)	c		Tr.; 0.58 <sup>-112</sup> <sub>(II)</sub>	(778)
CH <sub>3</sub> OH	liq.	251.1	+O <sub>2</sub>	(861, 948)
(see also p. 162)	gas	213.0	→liq.	(250.5, 346.5, 667.5, 904.5, 1003.5, 1053.5)
	aq.	259	8.4	(78)
	33.8	258.0	dil.	(223.5)
	16.0	257.7	dil.	
	7.11	256.6	dil.	
	4.15	255.4	dil.	
	2.67	254.4	dil.	
	1.19	252.9	dil.	
	0.44	252.0	dil.	
HC <sub>2</sub> O <sub>4</sub> <sup>-</sup>	aq.	814.8	NaHC <sub>2</sub> O <sub>4</sub>	
H <sub>2</sub> C <sub>2</sub> O <sub>4</sub>	c	824.6	+O <sub>2</sub> ; &	(56, 949, 976, 1013)

<sup>a</sup> For other compounds of carbon, see the section on Heats of Combustion, p. 162. For various reactions in C<sub>2</sub>H<sub>5</sub>OH, cf. (309, 311).

Formula	State	Q, kj	Method	Lit.
<b>Carbon.—(Continued)</b>				
H <sub>2</sub> C <sub>2</sub> O <sub>4</sub> —(Continued)....	gas	-734.0	→c*	(763*)
	aq.	814	-9.5 <sup>18</sup> <sub>300</sub> ; &	(56, 68, 976)
H <sub>2</sub> C <sub>2</sub> O <sub>4</sub> .2H <sub>2</sub> O	c	1422	-35.9 <sup>20</sup> <sub>200</sub>	(56, 459, 571, 571.5, 976)
C <sub>2</sub> H <sub>3</sub> O <sub>2</sub> <sup>-</sup>	aq.	492	NaC <sub>2</sub> H <sub>3</sub> O <sub>2</sub>	
HC <sub>2</sub> H <sub>3</sub> O <sub>2</sub>	c <sup>7</sup>	503	-0.0 <sup>7</sup> <sub>150</sub>	(49, 68, 235,* 800)
	liq.	492.6	+O <sub>2</sub>	(164, 838)
	gas	471.4	→liq.	(250.5, 468.5, 1072)
	200	494.1	dil.	(158,* 352, 976)
	100	494.0	dil.	
	50	493.7	dil.	
	20	493.3	dil.	
	8	492.6	dil.	
	4	492.1	dil.	
	2	491.9	dil.	
	1.5	491.9	dil.	
	1.0	491.9	dil.	
	0.5	492.0	dil.	
C <sub>2</sub> H <sub>3</sub> O <sup>-</sup>	C <sub>2</sub> H <sub>3</sub> OH	264	NaC <sub>2</sub> H <sub>3</sub> O	
C <sub>2</sub> H <sub>3</sub> OH	gas	233.5	→liq.	(904.5, 1053.5, 1072†)
(see also p. 162)	liq.	275.8	+O <sub>2</sub>	(15.5, 20, 164, 546.5, 650.5, 848, 861)
	200	286.99	dil.	(75, 223.50, 326, 652,* 827°)
	100	286.50	dil.	
	50	286.35	dil.	
	25	285.8	dil.	
	10.2	284.0	dil.	
	5.94	281.8	dil.	
	3.84	279.8	dil.	
	1.70	277.5	dil.	
	0.64	276.4	dil.	
	0.28	276.1	dil.	
C <sub>4</sub> H <sub>4</sub> O <sub>6</sub> <sup>-</sup>	aq.	1239	K <sub>2</sub> C <sub>4</sub> H <sub>4</sub> O <sub>6</sub>	
HC <sub>4</sub> H <sub>4</sub> O <sub>6</sub> <sup>-</sup>	aq.	1245	KHC <sub>4</sub> H <sub>4</sub> O <sub>6</sub>	
H <sub>2</sub> C <sub>4</sub> H <sub>4</sub> O <sub>6</sub> (d or l)	c	1263	+O <sub>2</sub>	(776)
H <sub>2</sub> C <sub>4</sub> H <sub>4</sub> O <sub>6</sub> (meso)	c	1269.5	-21.9	(71)
(H <sub>2</sub> C <sub>4</sub> H <sub>4</sub> O <sub>6</sub> ) <sub>2</sub> (d)	c	2541	-45.4	(71, 962)
H <sub>2</sub> C <sub>4</sub> H <sub>4</sub> O <sub>6</sub> (d, l, or d)	400	1247.5	-15.1 <sup>19</sup>	(54, 71, 976)
	200	1247.7	dil.	
	100	1247.8	dil.	
	50	1248.0	dil.	
	20	1248.6	dil.	
	6	1248.9	dil.	
CCl <sub>4</sub>	c		Tr.; 5 <sup>-48.6</sup> <sub>(I)</sub>	(613)
	gas	106.3	+H <sub>2</sub> ; &	(211.5, 976)
	liq.	138.9	→gas	(667.5, 848, 1003.5, 1053.5, 1072)
COCl <sub>2</sub>	gas	218	-O <sub>2</sub> ; &	(18,* 88, 212,* 213, 526,* 571.1,* 782,* 976)
	liq.	242.7	→gas	(441†)
COBr <sub>2</sub>	gas	92	dissoc.*	(958*)
(CS) <sub>x</sub>	c	-(54) <sub>x</sub>	+O <sub>2</sub>	(1086)
CS <sub>2</sub>	gas	- 120	liq.	(15.5, 593,† 792.5, 848, 1046.5)
	liq.	- 92	+O <sub>2</sub>	(101, 136, 592, 976)
COS	gas	92	+KOH; &	(84, 641,* 944, 976)
C <sub>2</sub> H <sub>5</sub> SO <sub>4</sub> <sup>-</sup>	aq.	904	NaC <sub>2</sub> H <sub>5</sub> SO <sub>4</sub>	
C <sub>2</sub> H <sub>5</sub> SO <sub>4</sub>	aq.	906	C <sub>2</sub> H <sub>5</sub> + H <sub>2</sub> SO <sub>4</sub> ; &	(74)
CN <sup>-</sup>	aq.	- 146	KCN	
C <sub>2</sub> N <sub>2</sub>	liq.	- 274	→gas	(268)
	gas	- 296	+O <sub>2</sub>	(147, 976)
	aq.	- 268	-28	(149, 496)
NCN <sub>2</sub>	c	- 396	dissoc.	(366)
NCN <sub>2</sub> (polymer.)	c	- 346	dissoc.	(366)



Formula	State	Q, kj	Method	Lit.	Formula	State	Q, kj	Method	Lit.
<b>Carbon.—(Continued)</b>					<b>Carbon.—(Continued)</b>				
CNO <sup>-</sup>	aq.	145	NaCNO		CNCl	gas	- 153	Hg(CN) <sub>2</sub> + Cl <sub>2</sub> ; &	(70)
C <sub>2</sub> N <sub>2</sub> O <sub>3</sub> <sup>-</sup>	aq.	558	Na <sub>2</sub> C <sub>2</sub> N <sub>2</sub> O <sub>3</sub>			liq.	- 118	—gas	(70)
CN <sub>2</sub> H <sup>-</sup>	aq.	- 95	NaHCN <sub>2</sub>		C <sub>2</sub> N <sub>2</sub> Cl <sub>2</sub>	c	29	+O <sub>2</sub> ; &	(626)
HCN	gas	- 126	+O <sub>2</sub> ; &	(53, 976)	CH <sub>2</sub> NH <sub>2</sub> HCl	aq.	306	N	(721)
	liq.	- 99.1	→gas; * &	(53, 233, * 499, * 791*)	C <sub>2</sub> N <sub>2</sub> CH <sub>4</sub>	c	105	+O <sub>2</sub>	(626)
	c <sup>-15</sup>	- 91.6	liq. *	(791, * 817*)	CNI	c	- 177	KCN + I	(70)
	aq.	- 100	25	(53, 258)		aq.	- 188	-11.6 <sup>20</sup> <sub>100</sub>	(70)
CH <sub>2</sub> NH <sub>2</sub>	gas	31	+O <sub>2</sub>	(626)	CNS <sup>-</sup>	aq.	- 76	KCNS	
	aq.	81	51	(221, 741, 976)	HCNS	aq.	- 77	N	(88)
					NH <sub>4</sub> CNS	c	81	-23.7 <sup>12</sup>	(88)
CH <sub>2</sub> NH <sub>2</sub> <sup>+</sup>	aq.	136	CH <sub>2</sub> NH <sub>2</sub> Cl			aq.	57	N	(88)
CN <sub>2</sub> H <sub>2</sub>	c	- 36	+O <sub>2</sub>	(626)	HSbOC <sub>4</sub> H <sub>4</sub> O <sub>4</sub>	c	1461	+HF; &	(468)
	liq.	- 45	→c*	(626†)	HSbOC <sub>4</sub> H <sub>4</sub> O <sub>4</sub> .4C <sub>4</sub> H <sub>4</sub> O <sub>4</sub>	aq.	6467	HSbOC <sub>4</sub> H <sub>4</sub> O <sub>4</sub> + C <sub>4</sub> H <sub>4</sub> O <sub>4</sub>	(468)
	aq.	- 52	-15 <sup>15</sup> <sub>1000</sub>	(626)					
NH <sub>4</sub> CN	c	4	-18.2 <sup>400</sup> ; &	(70, 543*)	<b>Silicon</b>				
(CH <sub>2</sub> ) <sub>2</sub> NH	aq.	- 14	N	(70)	Si	c	0	Def.	
	gas	32	+O <sub>2</sub>	(627, 741, 976)		amorp.	- 4	Si + O <sub>2</sub> ; &	(998, 1029)
					SiO <sub>2</sub>	gla.	830	Si + O <sub>2</sub>	(706, 825, 1029)
C <sub>2</sub> H <sub>2</sub> NH <sub>2</sub>	aq.	93	61.3 <sup>780</sup>	(221)	SiO <sub>2</sub> (α quartz)	c	842.6	+HF	(740, 829, 1042)
	gas	52	+O <sub>2</sub>	(102, 627, 976)	SiO <sub>2</sub> (β quartz)	c		Tr.;	(1042)
								0.6 <sup>573</sup> <sub>(α quartz)</sub>	
(CH <sub>2</sub> ) <sub>2</sub> N	aq.	106	54.0	(221)	SiO <sub>2</sub> (α cristobalite 1000)	c	839.5	+HF	(1042)
	gas	26	+O <sub>2</sub>	(102, 627, 741, 976)	SiO <sub>2</sub> (β cristobalite 1000)	c		Tr.; 0.6 <sub>(α crist.)</sub>	(1042)
					SiO <sub>2</sub> (α cristobalite 1000)	c	838.9	+HF	(1042)
(CN <sub>2</sub> H <sub>2</sub> ) <sub>2</sub>	aq.	80	54.2	(221)	SiO <sub>2</sub> (β cristobalite 1000)	c		Tr.; 0.2 <sub>(α crist.)</sub>	(1042)
	c	- 10.9	+O <sub>2</sub>	(626)	SiO <sub>2</sub> (β tridymite)	c		Tr.;	(1042)
	aq.	- 35.0	-24.1 <sup>15</sup>	(626)				0.1 <sub>(α tridymite)</sub>	
HCNO	aq.	153	+NH <sub>4</sub> OH	(70)	SiO <sub>2</sub> .H <sub>2</sub> O	coll.	826	+HF	(740)
NH <sub>4</sub> HCO <sub>3</sub>	c	850	-28 <sup>15</sup> <sub>1200</sub> ; &	(50, 361)	SiO <sub>2</sub> (H <sub>2</sub> O)	coll.	827	+HF	(740)
	400	822.7	dil.	(976)	SiO <sub>2</sub> (∞ H <sub>2</sub> O)	coll.	825		
	200	823.1	dil.		SiH <sub>4</sub>	gas	50	dissoc.; &	(768, 1029)
	100	824	N; &	(150)	H <sub>4</sub> SiO <sub>4</sub>	coll.	1397	= SiO <sub>2</sub> ∞	
	40	824.4	dil.		SiF <sub>4</sub>	gas	1512	HF + SiF <sub>4</sub>	(464, 468, 1000)
2NH <sub>3</sub> .CO <sub>2</sub>	c	650.0	-25; &	(226, * 227, * 621, * 679, 685, * 824)	SiF <sub>3</sub>				
					SiF <sub>2</sub>	aq.	2289	Na <sub>2</sub> SiF <sub>6</sub>	
CO(NH <sub>2</sub> ) <sub>2</sub>	aq.	626	N; &	(50, 679, 976)	H <sub>2</sub> SiF <sub>6</sub>	200	2281	HF + SiO <sub>2</sub>	(464, 468, 1000)
	c	328.5	+O <sub>2</sub>	(171, 331, 598, 980)				dil.	(1000)
								33	(1000)
NH <sub>4</sub> CNO	aq.	314.5	-14.0; &	(171, 789.50, 976)	SiCl <sub>4</sub>	gas	597	→liq.	(768)
	c	308	CO(NH <sub>2</sub> ) <sub>2</sub> ; &	(1026)	SiBr <sub>4</sub>	liq.	383	Si + Cl <sub>2</sub> ; &	(84, 768, 998)
(NH <sub>4</sub> ) <sub>2</sub> CO <sub>3</sub>	aq.	282	N	(1026)	SiI <sub>4</sub>	liq.	116	83 <sup>9</sup> <sub>2000</sub>	(84)
NH <sub>4</sub> CHO <sub>2</sub>	aq.	935	ions	(55, 73, 976)	SiS <sub>2</sub> (white)	c	134	86 <sup>9</sup> <sub>12000</sub>	(84)
	c	560	-12.0 <sup>10</sup> <sub>140</sub>	(55, 73, 976)	SiS <sub>2</sub> (yellow)	c	121	39 <sup>10</sup>	(897)
	400	548	N, analogy	(55)	Si <sub>3</sub> N <sub>4</sub>	c	634	45 <sup>10</sup>	(897)
								SiO <sub>2</sub> + N <sub>2</sub> + O <sub>2</sub> *	(681)
NH <sub>4</sub> CH <sub>2</sub> CO <sub>2</sub>	c	625	1.0 <sup>24</sup> <sub>200</sub>	(55)	(NH <sub>4</sub> ) <sub>2</sub> SiF <sub>6</sub>	c	2592	-35 <sup>7</sup> <sub>1200</sub>	(1002)
	400	625.9	N	(55)		aq.	2557	SiF <sub>4</sub> + NH <sub>4</sub> F; &	(1002)
	200	625.8	dil.	(328, † 976)	SiC	c	6	O <sub>2</sub> ; &	(768)
	100	625.4	dil.		(C <sub>2</sub> H <sub>5</sub> O) <sub>4</sub> SiO <sub>4</sub>	liq.	1309	90	(768)
	50	624.9	dil.						
	25	624.0	dil.		<b>Titanium<sup>a</sup></b>				
	10	622.3	dil.		Ti	c	0	Def.	
	5	620.1	dil.		TiO <sub>2</sub>	c	910	Ti + O <sub>2</sub> ; &	(709, 1028)
	2	618.6	dil.			amorp.	896	Ti + O <sub>2</sub> ; &	(709, 1028)
NH <sub>4</sub> HC <sub>2</sub> O <sub>4</sub>	400	948.7	N	(73)	TiO <sub>2</sub> (III) (rutile)	c		Tr.; 1.3 <sup>540</sup> <sub>(III)</sub>	(609)
CH <sub>2</sub> NH <sub>2</sub> .H <sub>2</sub> CO <sub>2</sub>	aq.	820	N	(741)	TiO <sub>2</sub> (II)	c		Tr.; 3.1 <sup>778</sup> <sub>(II)</sub>	(609)
(NH <sub>4</sub> ) <sub>2</sub> C <sub>2</sub> O <sub>4</sub>	c	1118	-33	(73)	TiO <sub>2</sub> (I)	c		Tr.; 1.1 <sup>600</sup> <sub>(III)</sub>	(609)
	400	1085	N	(73)	TiO <sub>2</sub> (III) (anatase)	c		Tr.; 1.6 <sup>735</sup> <sub>(II)</sub>	(609)
(NH <sub>4</sub> ) <sub>2</sub> C <sub>2</sub> O <sub>4</sub> .H <sub>2</sub> O	c	1419	-48	(73)	TiO <sub>2</sub> .xH <sub>2</sub> O	coll.	880 + xH <sub>2</sub> O	analogy	(709)
(CH <sub>2</sub> NH <sub>2</sub> ) <sub>2</sub> .H <sub>2</sub> CO <sub>2</sub>	aq.	930	N	(741)	TiF <sub>4</sub>	aq.	2327	Na <sub>2</sub> TiF <sub>6</sub>	
HC <sub>2</sub> N <sub>2</sub> O <sub>3</sub> <sup>-</sup>	aq.	608	Na <sub>2</sub> HC <sub>2</sub> N <sub>2</sub> O <sub>3</sub>		H <sub>2</sub> TiF <sub>6</sub>	aq.	2331	TiO <sub>2</sub> .xH <sub>2</sub> O + HF	(976)
H <sub>2</sub> C <sub>2</sub> N <sub>2</sub> O <sub>3</sub> <sup>-</sup>	aq.	650	NaH <sub>2</sub> C <sub>2</sub> N <sub>2</sub> O <sub>3</sub>						
C <sub>2</sub> N <sub>2</sub> H <sub>2</sub> O <sub>3</sub>	c	693	+O <sub>2</sub>	(626)					
	aq.	679	-13	(626)					
C <sub>2</sub> N <sub>2</sub> H <sub>2</sub> O <sub>3</sub> .2H <sub>2</sub> O	c	1281	-28.8	(626)					
NH <sub>4</sub> H <sub>2</sub> C <sub>2</sub> N <sub>2</sub> O <sub>3</sub>	aq.	781	N	(626)					
NH <sub>4</sub> H <sub>2</sub> C <sub>2</sub> N <sub>2</sub> O <sub>3</sub> .H <sub>2</sub> O	c	1114	-46.9 <sup>11</sup> <sub>460</sub> ; &	(626)					
(NH <sub>4</sub> ) <sub>2</sub> HC <sub>2</sub> N <sub>2</sub> O <sub>3</sub>	aq.	869	N	(626)					
(NH <sub>4</sub> ) <sub>2</sub> C <sub>2</sub> N <sub>2</sub> O <sub>3</sub>	aq.	955	N	(626)					
NH <sub>4</sub> HC <sub>2</sub> H <sub>2</sub> O <sub>3</sub>	400	1376	N	(56)					
(NH <sub>4</sub> ) <sub>2</sub> C <sub>2</sub> H <sub>2</sub> O <sub>3</sub>	400	1507	N	(56)					
	200	1507.7	dil.	(976)					
	100	1508.0	dil.						
	50	1509.6	dil.						
	30	1511.0	dil.						
	21	1511.9	dil.						

<sup>a</sup> TiCl<sub>3</sub> (brown) heat of solution 48.6, TiCl<sub>3</sub> (blue) heat of solution 45.8 (207).



Formula	State	Q. kj	Method	Lit.
<b>Titanium.—(Continued)</b>				
TiCl <sub>4</sub> .....	liq.	768	242 <sup>18</sup> <sub>2000</sub>	(207, 976)
H <sub>2</sub> TiCl <sub>6</sub> .....	aq.	1350	TiCl <sub>4</sub> + HCl aq.	(976)
<b>Zirconium<sup>a</sup></b>				
Zr.....	c	0	Def.	
ZrO <sub>2</sub> .....	gls.	748	Zr + O <sub>2</sub>	(1040)
Zr(OH) <sub>4</sub> .....	ppt.		N	(270)
ZrOCl <sub>2</sub> .....	aq.			
ZrOCl <sub>2</sub> ·2H <sub>2</sub> O.....	c		67	(269)
ZrOCl <sub>2</sub> ·3H <sub>2</sub> O.....	c		38	(269)
ZrOCl <sub>2</sub> ·6H <sub>2</sub> O.....	c		3	(269)
ZrOCl <sub>2</sub> ·8H <sub>2</sub> O.....	c		-13	(269)
ZrOBr <sub>2</sub> ·3H <sub>2</sub> O.....	c		37.7	(271)
ZrOBr <sub>2</sub> ·8H <sub>2</sub> O.....	c		-8.4	(271)
ZrO(NO <sub>3</sub> ) <sub>2</sub> ·2H <sub>2</sub> O.....	c		9.1	(273)
ZrO(NO <sub>3</sub> ) <sub>2</sub> ·3H <sub>2</sub> O(?).....	c		-2.1	(273)
ZrO(NO <sub>3</sub> ) <sub>2</sub> ·3H <sub>2</sub> O.....	c		-8.0	(273)
ZrO(NO <sub>3</sub> ) <sub>2</sub> ·6H <sub>2</sub> O.....	c		-24.7	(273)
ZrOSO <sub>4</sub> ·4H <sub>2</sub> O.....	c		43	(272)
ZrOSO <sub>4</sub> ·SO <sub>3</sub> .....	c		137.2	(272)
ZrOSO <sub>4</sub> ·H <sub>2</sub> SO <sub>4</sub> .....	c		86	(272)
ZrC.....	c	146	ZrO + C*	(626*)

**Tin**

Sn(rhom.).....	c		Tr.: 0.04 <sup>161</sup> <sub>(tetrag.)</sub>	(1046)
Sn(tetrag.).....	c	0	Def.	
Sn(gray).....	c	- 2.2	Tr.: 2.2 <sup>9</sup> <sub>(tetrag.)</sub>	(242, 262, 692)
Sn <sup>++</sup> .....	aq.	10	SnCl <sub>2</sub>	
Sn <sup>+++</sup> .....	aq.	- 4	SnCl <sub>4</sub>	
SnO.....	c	292	+ O <sub>2</sub>	(322, 798)
SnO <sub>2</sub> (fused).....	c	578	Sn + O <sub>2</sub> ; &	(302)
SnO <sub>2</sub> <sup>-</sup> .....	aq.	456	Na <sub>2</sub> SnO <sub>2</sub>	
SnO <sub>2</sub> (II) (cassiterite).....	c		Tr.: 1.3 <sup>540</sup> <sub>(III)</sub>	(609)
SnO <sub>2</sub> (I) (cassiterite).....	c		Tr.: 1.9 <sup>430</sup> <sub>(II)</sub>	(609)
Sn(OH) <sub>2</sub> .....	coll.	570.7	SnCl <sub>2</sub> + NaOH	(976)
H <sub>4</sub> SnO <sub>4</sub> (fresh).....	coll.	1357	SnCl <sub>4</sub> + KOH	(976, 1014)
SnF <sub>6</sub> <sup>-</sup> .....	aq.	1963	N = H <sub>2</sub> SiF <sub>6</sub>	
H <sub>2</sub> SnF <sub>6</sub> .....	aq.	1967	SnCl <sub>4</sub> + HF	(976)
SnCl <sub>2</sub> .....	c	339.6	1.5 <sup>18</sup> <sub>200</sub>	(84, 976)
SnCl <sub>2</sub> (HCl).....	aq.	341.1	+ Zn; &	(759, 976)
SnCl <sub>2</sub> ·2H <sub>2</sub> O.....	c	936	-22.1 <sup>18</sup> <sub>200</sub>	(84, 188, 976)
SnCl <sub>4</sub> .....	liq.	533	125.2 <sup>20</sup> <sub>260</sub>	(84, 976)
SnCl <sub>4</sub> (HCl).....	gas	495	→liq.	(15.3, 1072)
SnCl <sub>4</sub> (HCl).....	aq.	658.2	SnCl <sub>2</sub> + HClO <sub>2</sub> ; &	(69, 976)
SnCl <sub>6</sub> <sup>2-</sup> .....	aq.	988	K <sub>2</sub> SnCl <sub>6</sub>	
H <sub>2</sub> SnCl <sub>6</sub> .....	aq.	989	-SnCl <sub>4</sub> + HCl	
SnBr <sub>2</sub> .....	c	257	-7	(84, 168)
SnBr <sub>2</sub> .....	aq.	251	+ KCl	(84)
SnBr <sub>4</sub> .....	liq.	386	→c <sup>21</sup>	(84, 422, † 983)
.....	c	398	69	(84, 984)
.....	aq.	467	SnCl <sub>4</sub> + KBr	(84, 611)
SnI <sub>2</sub> .....	c	150	analogy	(188)
.....	aq.	138	+ KCl	(84)
SnCl <sub>2</sub> ·2NH <sub>3</sub> .....	c	614	+58.6HCl	(188*)
SnCl <sub>2</sub> ·4NH <sub>3</sub> .....	c	678	dissoc.*	(188*)
SnCl <sub>2</sub> ·9NH <sub>3</sub> .....	c	1067	dissoc.*	(188*)
SnBr <sub>2</sub> ·NH <sub>3</sub> .....	c	384	dissoc.*	(188*)
SnBr <sub>2</sub> ·2NH <sub>3</sub> .....	c	487	+ HCl; &	(188*)
SnBr <sub>2</sub> ·3NH <sub>3</sub> .....	c	585	+ HCl; &	(188*)
SnBr <sub>2</sub> ·5NH <sub>3</sub> .....	c	759	dissoc.*	(188*)
SnBr <sub>2</sub> ·9NH <sub>3</sub> .....	c	1069	dissoc.*	(188*)
SnI <sub>2</sub> ·NH <sub>3</sub> .....	c	263	dissoc.*	(188*)
SnI <sub>2</sub> ·2NH <sub>3</sub> .....	c	365	+ HCl; &	(188*)
SnI <sub>2</sub> ·3NH <sub>3</sub> .....	c	460	+ HCl; &	(188*)
SnI <sub>2</sub> ·5NH <sub>3</sub> .....	c	637	dissoc.*	(188*)
SnI <sub>2</sub> ·9NH <sub>3</sub> .....	c	953	dissoc.*	(188*)
SnS.....	c	100	+ H <sub>2</sub> *	(8630)

\* Includes 0-2 % Hafnium.

Formula	State	Q. kj	Method	Lit.
<b>Lead<sup>a</sup></b>				
Pb.....	c	0	Def.	
Pb <sub>(stick)</sub> .....	c	- 0.3	+ Hg*	(439*)
Pb <sup>++</sup> .....	aq.	2	Pb(NO <sub>3</sub> ) <sub>2</sub>	
PbO <sub>(red)</sub> .....	c	219.6	+ H <sub>2</sub> ; &	(921, * 993*, 1080*)
PbO <sub>2</sub> .....	c	262	+ SO <sub>2</sub> ; &	(274, 265*, 709)
Pb <sub>2</sub> O.....	c	214.5	+ H <sub>2</sub> C <sub>2</sub> O <sub>4</sub>	(512)
Pb <sub>2</sub> O <sub>4</sub> .....	c	729	dissoc.*	(620, 851*)
Pb(OH) <sub>2</sub> .....	ppt.	576	Pb(NO <sub>3</sub> ) <sub>2</sub> + NaOH	(88, 976)
PbF <sub>2</sub> .....	c	667.1	Pb(NO <sub>3</sub> ) <sub>2</sub> + HF	(464, 465)
PbCl <sub>2</sub> .....	c	358.5	Pb + Cl <sub>2</sub> *; &	(229, 230, 248, * 439*, 594, * 780)
.....	aq.	331.1	-27.4	(88, 248, † 976)
PbCl <sub>2</sub> ·PbO.....	c	597	76HCl	(11)
PbCl <sub>2</sub> ·2PbO.....	c	820	167HCl	(11)
PbCl <sub>2</sub> ·3PbO.....	c	1037	265HCl	(11)
PbBr <sub>2</sub> .....	c	277.3	K <sub>2</sub> C <sub>4</sub> H <sub>4</sub> O <sub>6</sub> ; &	(229, 976)
.....	aq.	235.3	-42.0 <sup>18</sup> <sub>2500</sub>	(976)
PbBr <sub>2</sub> ·PbO.....	c	501	104HBr	(11)
PbBr <sub>2</sub> ·2PbO.....	c	717	209HBr	(11)
PbBr <sub>2</sub> ·3PbO.....	c	935	316HBr	(11)
PbI <sub>2</sub> .....	c	175.1	Pb + I; &	(229, 230, 439, * 967)
PbI <sub>2</sub> ·HI·5H <sub>2</sub> O.....	c	1678	-16 <sup>11</sup> <sub>200</sub>	(130)
PbS.....	ppt.	93	Pb(NO <sub>3</sub> ) <sub>2</sub> + Na <sub>2</sub> S	(60, 553, 967*, 976)
PbSO <sub>4</sub> (I).....	c		Tr.: 17.0 <sup>866</sup> <sub>(II)</sub>	(1001)
PbSO <sub>4</sub> (II).....	c	898	Pb(NO <sub>3</sub> ) <sub>2</sub> + H <sub>2</sub> SO <sub>4</sub> ; &	(976)
PbS <sub>2</sub> O <sub>3</sub> .....	c	616	Na <sub>2</sub> S <sub>2</sub> O <sub>3</sub> + NaC <sub>2</sub> H <sub>3</sub> O <sub>2</sub>	(369)
PbS <sub>2</sub> O <sub>4</sub> .....	aq.	1150	Pb <sup>++</sup> + S <sub>2</sub> O <sub>4</sub> <sup>-</sup>	
PbS <sub>2</sub> O <sub>4</sub> ·4H <sub>2</sub> O.....	c	2330	-35.7 <sup>18</sup> <sub>400</sub>	(976)
PbS <sub>2</sub> O <sub>5</sub> .....	c	1119	-20.9	(369)
PbSe.....	aq.	1097	ions	
.....	ppt.	99	Pb(C <sub>2</sub> H <sub>3</sub> O <sub>2</sub> ) <sub>2</sub> + H <sub>2</sub> Se	(350)
.....	c	52	+ Br aq.	(350)
PbSeO <sub>4</sub> .....	c	627	Na <sub>2</sub> SeO <sub>4</sub> + Pb(NO <sub>3</sub> ) <sub>2</sub>	(696)
PbTe.....	c	23 (?)	+ Br	(351)
PbN <sub>4</sub> .....	c	- 421	dissoc.	(1113)
Pb(NO <sub>3</sub> ) <sub>2</sub> .....	c	453.2	-31.8 <sup>18</sup> <sub>400</sub>	(84, 989, 976)
.....	400	421.3	dil.	
.....	200	423.5	PbCl <sub>2</sub> + HNO <sub>3</sub> ; &	(976)
.....	100	426.7	dil.	
.....	40	431.8	dil.	
Pb(NO <sub>3</sub> ) <sub>2</sub> ·PbO.....	c	707	Pb(NO <sub>3</sub> ) <sub>2</sub> + NaOH	(976)
PbCl <sub>2</sub> ·NH <sub>3</sub> .....	c	456	dissoc.*	(184*)
PbCl <sub>2</sub> ·1NH <sub>3</sub> .....	c	506	dissoc.*	(184*)
PbCl <sub>2</sub> ·2NH <sub>3</sub> .....	c	552	dissoc.*	(184*, 335)
PbCl <sub>2</sub> ·3NH <sub>3</sub> .....	c	659	dissoc.*	(184*)
PbCl <sub>2</sub> ·8NH <sub>3</sub> .....	c	1040	dissoc.*	(184*)
2PbCl <sub>2</sub> ·NH <sub>4</sub> Cl.....	c	1032.7	PbCl <sub>2</sub> + NH <sub>4</sub> Cl	(344)
PbBr <sub>2</sub> ·NH <sub>3</sub> .....	c	388	dissoc.*	(184*)
PbBr <sub>2</sub> ·2NH <sub>3</sub> .....	c	482	dissoc.*	(184*, 335*)
PbBr <sub>2</sub> ·3NH <sub>3</sub> .....	c	567	dissoc.*	(184*)
PbBr <sub>2</sub> ·5NH <sub>3</sub> .....	c	777	dissoc.*	(184*)
PbBr <sub>2</sub> ·8NH <sub>3</sub> .....	c	977	dissoc.*	(184*)
PbI <sub>2</sub> ·NH <sub>3</sub> .....	c	228	dissoc.*	(184*)
PbI <sub>2</sub> ·NH <sub>3</sub> .....	c	279	dissoc.*	(184*)
PbI <sub>2</sub> ·2NH <sub>3</sub> .....	c	372	dissoc.*	(184*)
PbI <sub>2</sub> ·5NH <sub>3</sub> .....	c	631	dissoc.*	(184*, 335*)
PbI <sub>2</sub> ·8NH <sub>3</sub> .....	c	866	dissoc.*	(184*)
PbSO <sub>4</sub> ·(NH <sub>4</sub> ) <sub>2</sub> SO <sub>4</sub> .....	c	2068.0	PbSO <sub>4</sub> + (NH <sub>4</sub> ) <sub>2</sub> SO <sub>4</sub>	(30)
PbHPO <sub>3</sub> .....	c	970	Na <sub>2</sub> HPO <sub>3</sub> + Pb(NO <sub>3</sub> ) <sub>2</sub>	(8)
PbCO <sub>3</sub> .....	c	707	+ HNO <sub>3</sub>	(88, 666)
.....	ppt.	703	+ HNO <sub>3</sub>	(666, 976)

\* Alloys with Sn (688).



Formula	State	Q. kj	Method	Lit.
<b>Lead.—(Continued)</b>				
PbCO <sub>3</sub> .PbO	c	928	+HNO <sub>3</sub>	(668, 1035)
PbCO <sub>3</sub> .2PbO	c	1151	dissoc.*	(1005)
PbC <sub>2</sub> O <sub>4</sub>	c	863	Pb(NO <sub>3</sub> ) <sub>2</sub> + K <sub>2</sub> C <sub>2</sub> O <sub>4</sub>	(58, 668)
Pb(CHO <sub>2</sub> ) <sub>2</sub>	c	859	-29 <sup>10</sup>	(55)
	aq.	830	Pb(OH) <sub>2</sub> + HCHO <sub>2</sub>	(55)
Pb(CH <sub>3</sub> CO <sub>2</sub> ) <sub>2</sub>	c	979.3	5.9 <sup>11</sup> <sub>220</sub>	(55)
	aq.	985.4	PbO + HC <sub>2</sub> H <sub>3</sub> O <sub>2</sub> ; & -23 <sup>11</sup> <sub>100</sub>	(55, 976)
Pb(CH <sub>3</sub> CO <sub>2</sub> ) <sub>2</sub> .3H <sub>2</sub> O	c	1867	-23 <sup>11</sup> <sub>100</sub>	(55)
PbO.Pb(CH <sub>3</sub> CO <sub>2</sub> ) <sub>2</sub>	c	1226	Pb(C <sub>2</sub> H <sub>3</sub> O <sub>2</sub> ) <sub>2</sub> + NaOH; & 154 <sup>19</sup> <sub>HNO<sub>3</sub></sub>	(976)
Pb(CN) <sub>2</sub> .2PbO.H <sub>2</sub> O	c	523	154 <sup>19</sup> <sub>HNO<sub>3</sub></sub>	(555)
Pb(CNS) <sub>2</sub>	c	-120	Pb(C <sub>2</sub> H <sub>3</sub> O <sub>2</sub> ) <sub>2</sub> + KCNS	(555)

**Thorium**

Th	c	0	Def.	
Th <sup>++</sup> (?)	aq.	998	ThCl <sub>4</sub>	
ThO <sub>2</sub>	c	1385	Th + O <sub>2</sub>	(268, 1028)
ThH <sub>4</sub>	c	-179	dissoc.	(684)
Th(OH) <sub>4</sub> (dried ppt.)	ppt.	1407	+HCl	(268)
Th <sub>2</sub> (OH) <sub>4</sub> (condensed)	ppt.	1360	+HCl	(268)
ThCl <sub>4</sub>	c	1402	237 <sup>15</sup> ; & Th + HCl	(268, 1028)
	aq.	1641		(268)
ThCl <sub>4</sub> .2H <sub>2</sub> O	c	2041	171.9	(268)
ThCl <sub>4</sub> .4H <sub>2</sub> O	c	2675	109.8	(268)
ThCl <sub>4</sub> .7H <sub>2</sub> O	c	3582	61	(268)
ThCl <sub>4</sub> .8H <sub>2</sub> O	c	3882	47.9	(268)
ThOCl <sub>2</sub>	c	1410	117.8	(268)
ThCl <sub>3</sub> OH.H <sub>2</sub> O	c	1669	199	(268)
ThBr <sub>4</sub>	c	1176	293.7	(268)
	aq.	1470	ions	(268)
ThBr <sub>4</sub> .7H <sub>2</sub> O	c	3379	94.4	(268)
ThBr <sub>4</sub> .10H <sub>2</sub> O	c	4291	41.2	(268)
ThBr <sub>4</sub> .12H <sub>2</sub> O	c	4895	10	(268)
ThOBr <sub>2</sub>	c	1334	117.0	(268)
ThI <sub>4</sub>	aq.	1221	ions	(268)
ThOI <sub>2</sub>	c	1212	90.1	(268)
ThOI <sub>2</sub> .3H <sub>2</sub> O	c	1781	42	(268)
ThI <sub>2</sub> OH.10H <sub>2</sub> O	c	3812	35.3	(268)
Th(SO <sub>4</sub> ) <sub>2</sub>	aq.	2770	ions	
Th(SO <sub>4</sub> ) <sub>2</sub> .4H <sub>2</sub> O	c	3893	21	(591)
Th(SO <sub>4</sub> ) <sub>2</sub> .8H <sub>2</sub> O	c	5090	-31	(591)
ThCl <sub>4</sub> .2NH <sub>4</sub> Cl	c	2069	166.6	(268)
ThCl <sub>4</sub> .2NH <sub>4</sub> Cl.10H <sub>2</sub> O	c	5114	-16	(268)
ThCl <sub>4</sub> .4NH <sub>3</sub>	c	1920	258HCl	(268)
ThCl <sub>4</sub> .6NH <sub>3</sub> (α)	c	2142	306.0HCl	(268)
[Th.6NH <sub>3</sub> ]Cl <sub>4</sub> (β)	c	2297	148HCl	(268)
ThCl <sub>4</sub> .7NH <sub>3</sub> (α)	c	2194	346.3HCl	(268)
[Th.6NH <sub>3</sub> ]Cl <sub>4</sub> .NH <sub>3</sub> (β)	c	2435	142.9HCl	(268)
ThCl <sub>4</sub> .12NH <sub>3</sub> (α)	c	2672	585HCl	(268)
[Th.6NH <sub>3</sub> ]Cl <sub>4</sub> .6NH <sub>3</sub> (β)	c	2864	392HCl	(268)
ThCl <sub>4</sub> .18NH <sub>3</sub> (α)	c	3127	896HCl	(268)
[Th.6NH <sub>3</sub> ]Cl <sub>4</sub> .12NH <sub>3</sub> (β)	c	3304	719HCl	(268)
Th(CO <sub>3</sub> ) <sub>2</sub>	(?)	3579	ThSO <sub>4</sub> .4H <sub>2</sub> O + K <sub>2</sub> CO <sub>3</sub>	(591)

**Indium<sup>a</sup>**

In	c	0	Def.	
In <sup>++</sup>	aq.	113	InCl <sub>3</sub>	
In <sub>2</sub> O <sub>3</sub>	c	100	+O <sub>2</sub>	(315)
InCl	c	187	+KBr + Cl <sub>2</sub>	(1099*)
InCl <sub>2</sub>	c	363	+KBr + Cl <sub>2</sub>	(1099*)
InCl <sub>3</sub>	c	538	In + Cl <sub>2</sub>	(1099*)
	aq.	608	71HCl(m)	(1098*)
InBr <sub>3</sub>	c	407	65HCl(22)	(1098*)
	aq.	472	ions	
InI <sub>3</sub>	c	136	44HCl(22)	(1098*)
	aq.	280	ions	
InCl <sub>3</sub> .NH <sub>3</sub>	c	675	64HCl(22)	(1098*)
InCl <sub>3</sub> .2NH <sub>3</sub>	c	806	66HCl(22)	(1098*)
InCl <sub>3</sub> .3NH <sub>3</sub>	c	934	70HCl(22)	(1098*)
InCl <sub>3</sub> .5NH <sub>3</sub>	c	1125	144HCl(22)	(1098*)

Indium amalgams, heat of dilution (873).

Formula	State	Q. kj	Method	Lit.
<b>Indium.—(Continued)</b>				
InCl <sub>3</sub> .7NH <sub>3</sub>	c	1288	dissoc.*	(1098*)
InCl <sub>3</sub> .15NH <sub>3</sub>	c	2246	dissoc.*	(1098*)
InBr <sub>3</sub> .3NH <sub>3</sub>	c	797	72HCl(22)	(1098*)
InBr <sub>3</sub> .5NH <sub>3</sub>	c	1001	129HCl(22)	(1098*)
InBr <sub>3</sub> .7NH <sub>3</sub>	c	1170	228HCl(22)	(1098*)
InBr <sub>3</sub> .15NH <sub>3</sub>	c	1810	dissoc.*	(1098*)
InI <sub>3</sub> .NH <sub>3</sub>	c	367	dissoc.*	(1098*)
InI <sub>3</sub> .2NH <sub>3</sub>	c	486	59HCl(22)	(1098*)
InI <sub>3</sub> .5NH <sub>3</sub>	c	826	116HCl(22)	(1098*)
InI <sub>3</sub> .7NH <sub>3</sub>	c	1012	194HCl(22)	(1098*)
InI <sub>3</sub> .9NH <sub>3</sub>	c	1176	dissoc.*	(1098*)
InI <sub>3</sub> .13NH <sub>3</sub>	c	1491	dissoc.*	(1098*)
InI <sub>3</sub> .21NH <sub>3</sub>	c	2101	dissoc.*	(1098*)

**Thallium<sup>a</sup>**

Tl <sub>(I)</sub>	c		Tr; 0.21 <sup>226</sup> <sub>(II)</sub>	(1045)
Tl <sub>(II)</sub>	c	0	Def.	
Tl <sup>+</sup>	aq.	-4	TlOH	
Tl <sup>++</sup>	aq.	-123	TlBr <sub>3</sub>	
Tl <sub>2</sub> O	c	176.4	-12.9 <sup>18</sup> <sub>870</sub>	(26, 976)
TlOH	c	238.0	-13.2 <sup>18</sup> <sub>235</sub>	(423, 976)
Tl(OH) <sub>3</sub>	aq.	224.8	+HCl	(976)
TlF	c	607.1	+HBr	(976)
TlF	aq.	323.5	N	(423, 792)
HTlF <sub>2</sub>	800	637.4	HF + TlF	(792)
TlCl	c	203.8	Tl + PbCl <sub>2</sub> *; & -42 <sup>18</sup> <sub>4500</sub>	(423, 976)
	aq.	161		
TlCl <sub>2</sub>	c	337.9	+35.3 <sub>300</sub>	(972)
	aq.	373.2	ions	(976)
TlCl <sub>3</sub> .4H <sub>2</sub> O	c	1527.1	-8.9 <sub>300</sub>	(972)
TlBr	c	171.8	Tl <sub>2</sub> SO <sub>4</sub> + HBr; &	(976)
	aq.	236.1	+SO <sub>2</sub>	(976)
TlBr <sub>3</sub> .4H <sub>2</sub> O	c	1390.2	-9.4 <sub>450</sub>	(972)
TlBr <sub>2</sub> Cl	aq.	282	TlBr <sub>3</sub> + TlCl <sub>3</sub>	(972)
TlBr <sub>2</sub> Cl.4H <sub>2</sub> O	c	1438.9	-12.1 <sub>300</sub>	(976)
TlI	c	126.0	Tl <sub>2</sub> SO <sub>4</sub> + HI	(976)
Tl <sub>2</sub> S	c	92	Na <sub>2</sub> S + TlNO <sub>3</sub>	(976)
	c	911.4	-34.6 <sup>18</sup> <sub>1600</sub>	(976)
Tl <sub>2</sub> SO <sub>4</sub>	800	876.8	N; &	(976)
	200	878.2	dil.	(423, 976)
Tl <sub>2</sub> Se	c	50	+Br	(351)
	ppt.	50	TlC <sub>2</sub> H <sub>3</sub> O <sub>2</sub> + H <sub>2</sub> Se	(351)
Tl <sub>2</sub> Te	c	30	+Br	(351)
TlN <sub>3</sub>	c	-229	dissoc.	(1113)
TlNO <sub>3</sub> (I)	c		Tr; 3.2 <sup>145</sup> <sub>(II)</sub>	(234*)
TlNO <sub>3</sub> (II)	c		Tr; 1.0 <sup>75</sup> <sub>(III)</sub>	(234*)
TlNO <sub>3</sub> (III)	c	246.1	-41.7 <sup>18</sup> <sub>300</sub>	(976)
	aq.	204.4	N	(976)
TlCl <sub>3</sub> .3NH <sub>3</sub>	c	431	dissoc.*	(196)
TlBr <sub>3</sub> .3NH <sub>3</sub>	c	398	dissoc.*	(196)
TlI <sub>3</sub> .3NH <sub>3</sub>	c	353	dissoc.*	(196)
TlOC <sub>2</sub> H <sub>5</sub>	c	230	-2.2	(423.5)
	C <sub>2</sub> H <sub>5</sub> OH	232	Tl + C <sub>2</sub> H <sub>5</sub> OH	(423.5)
TlC <sub>2</sub> H <sub>3</sub> O <sub>2</sub>	aq.	488	N; &	(423)
TlONC	c	-109	dissoc.	(1113)

**Zinc<sup>b</sup>**

Zn	c	0	Def	
	gas	-131	→c*	(329, 460, 516, 517, 536, 557, 593, 792, 876, 1069*)
Zn <sup>++</sup>	aq.	153	ZnSO <sub>4</sub>	(444)
ZnO(fused)	c	353	Zn + O <sub>2</sub> ; &	(16, 95, 307, 308, 315, 323, 359, 390, 499, 659, 666, 711, 730.5, 1067)
ZnO(low temp.)	c	349	105.6H <sub>2</sub> SO <sub>4</sub> (200); &	(390, 659, 666)

<sup>a</sup> Tl<sub>2</sub>SO<sub>4</sub>.10NH<sub>3</sub> (343). Thallium amalgams (860, 870, 873).<sup>b</sup> For heat of dissociation of the amines of various zinc salts, v. (335, 339, 341). Alloys with Sn (658).



Formula	State	Q, kj	Method	Lit.
<b>Zinc.—(Continued)</b>				
Zn(OH) <sub>2</sub> (?)	c	663	79H <sub>2</sub> SO <sub>4</sub> (200)	(390, 717)
Zn(OH) <sub>2</sub>	amorp.	642.3	ZnSO <sub>4</sub> + KOH; &	(390, 976)
			+ H <sub>2</sub> SO <sub>4</sub>	(390)
Zn(OH) <sub>2</sub> .H <sub>2</sub> O (ordin. ppt.)	amorp.	928.5	62.2H <sub>2</sub> SO <sub>4</sub> (200)	(390)
ZnO <sub>2</sub> .2H <sub>2</sub> O	c	1056	64.8H <sub>2</sub> SO <sub>4</sub> (200)	(390)
ZnO <sub>2</sub> .H <sub>2</sub> O	c	454	201.4H <sub>2</sub> SO <sub>4</sub> (200)	(390)
Zn <sub>2</sub> O <sub>3</sub> .2H <sub>2</sub> O	c	1543	ZnCl <sub>2</sub> + AgF	(793)
ZnF <sub>2</sub>	aq.	804.8	65.8 <sup>18</sup> <sub>400</sub>	(32, 311, 976)
ZnCl <sub>2</sub>	c	416.6		(188, 197, 858, 872, 919, 933, 1087, 1099)
	400	482.4	Zn + HCl; &	(976)
	200	480.8	dil.	
	100	477.3	dil.	
	50	471.0	dil.	
	20	461.9	dil.	
	10	456.4	dil.	
	5	448.6	dil.	
ZnCl <sub>2</sub> .3ZnO.5H <sub>2</sub> O	c	2952	257HCl	(11)
ZnCl <sub>2</sub> .4ZnO.11H <sub>2</sub> O	c	5040	321HCl	(11)
ZnCl <sub>2</sub> .5ZnO.8H <sub>2</sub> O	c	4536	400HCl	(11)
ZnCl <sub>2</sub> .8ZnO.10H <sub>2</sub> O	c	6188	621HCl	(11)
ZnBr <sub>2</sub>	c	326	62.9	(11, 976)
	400	389	ZnSO <sub>4</sub> + BaBr <sub>2</sub> ; &	(511, 976)
			326HBr	(11)
ZnBr <sub>2</sub> .4ZnO.13H <sub>2</sub> O	c	5517	49; & *	(1035, 1093*)
ZnI <sub>2</sub>	c	208	Zn + I <sub>2</sub>	(1036)
	650	257	484HI	(966)
ZnI <sub>2</sub> .5ZnO.11H <sub>2</sub> O	c	3935	+ Na <sub>2</sub> O <sub>2</sub>	(715)
ZnS	c	192	Zn(C <sub>2</sub> H <sub>5</sub> O <sub>2</sub> ) <sub>2</sub>	(60, 976)
	ppt.	173	+ H <sub>2</sub> S; &	
			Zn + SO <sub>2</sub>	(78)
ZnSO <sub>3</sub>	aq.	616	77.6 <sup>17</sup> <sub>400</sub>	(458, 694, 976)
ZnSO <sub>4</sub>	c	960.5		(976)
	400	1038.1	+ NaOH; &	(390, 976)
	200	1038.1	dil.	(976)
	100	1038.0	dil.	
	50	1037.8	dil.	
	20	1036.4	dil.	
ZnSO <sub>4</sub> .H <sub>2</sub> O	c	1282.4	41.8 <sup>18</sup> <sub>400</sub>	(458, 976*)
ZnSO <sub>4</sub> .6H <sub>2</sub> O	c	2759	-3.5 <sup>18</sup> <sub>400</sub>	(387, 388, 429, 740, 850, 976)
ZnSO <sub>4</sub> .7H <sub>2</sub> O	c	3059.2	-17.9 <sup>18</sup> <sub>400</sub>	(429, 458, 694, 976)
ZnS <sub>2</sub> O <sub>4</sub>	aq.	818	ions	
ZnS <sub>2</sub> O <sub>6</sub>	400	1301	ions	
ZnS <sub>2</sub> O <sub>8</sub> .6H <sub>2</sub> O	c	3028.0	-9.4	(976)
ZnSe	c	140	+ Br <sub>2</sub>	(380)
	ppt.	131	Zn(C <sub>2</sub> H <sub>5</sub> O <sub>2</sub> ) <sub>2</sub> + Na <sub>2</sub> Se	(380)
			+ Br	(381)
ZnTe	c	139	dissoc.	(1112)
ZnN <sub>2</sub>	c	213		
Zn(NO <sub>2</sub> ) <sub>2</sub>	400	569.6	ions	(976)
	200	569.7	dil.	
	100	569.9	dil.	
	50	570.2	dil.	
	20	570.0	dil.	
	15	569.0	dil.	
	10	565.2	dil.	
	3	556	extrap.	
Zn(NO <sub>2</sub> ) <sub>2</sub> .3H <sub>2</sub> O	c	1450	→liq.	(1105)
Zn(NO <sub>2</sub> ) <sub>2</sub> .6H <sub>2</sub> O	c	2311.1	-24.5 <sup>18</sup> <sub>400</sub>	(732, 976)
ZnCl <sub>2</sub> .NH <sub>3</sub>	c	566	dissoc.*	(193*)
ZnCl <sub>2</sub> .2NH <sub>3</sub>	c	693.2	+ HCl; &	(193, 339)
ZnCl <sub>2</sub> .4NH <sub>3</sub>	c	884	+ HCl; &	(193, 339)
ZnCl <sub>2</sub> .6NH <sub>3</sub>	c	1068	+ HCl; &	(193, 339, 339, 339*)
ZnCl <sub>2</sub> .10NH <sub>3</sub>	c	1870	dissoc.*	(193, 334*)
ZnCl <sub>2</sub> .5NH <sub>3</sub> .H <sub>2</sub> O	c	1231	196HCl	(11)
ZnCl <sub>2</sub> .2NH <sub>3</sub> .H <sub>2</sub> O	c	757	57.5HCl(100)	(11)
ZnCl <sub>2</sub> .ZnO.8NH <sub>4</sub> Cl	c	3254	40HCl	(11)
3ZnCl <sub>2</sub> .6NH <sub>4</sub> Cl.H <sub>2</sub> O	c	3478	27	(11)
3ZnCl <sub>2</sub> .ZnO.10NH <sub>4</sub> Cl	c	3822	68HCl	(11)
6ZnCl <sub>2</sub> .ZnO.12NH <sub>3</sub>	c	5639	400HCl	(11)
ZnBr <sub>2</sub> .NH <sub>3</sub>	c	514	dissoc.*	(193*)

Formula	State	Q, kj	Method	Lit.
<b>Zinc.—(Continued)</b>				
ZnBr <sub>2</sub> .2NH <sub>3</sub>	c	644	dissoc.*	(193, 339*)
ZnBr <sub>2</sub> .4NH <sub>3</sub>	c	849	dissoc.*; &	(11, 193, 332, 334*)
ZnBr <sub>2</sub> .6NH <sub>3</sub>	c	1032	dissoc.*	(193*)
ZnBr <sub>2</sub> .6NH <sub>3</sub> .H <sub>2</sub> O	c	1319	153HBr	(11)
ZnI <sub>2</sub> .NH <sub>3</sub>	c	345	dissoc.*	(193*)
ZnI <sub>2</sub> .2NH <sub>3</sub>	c	471	dissoc.*	(193*)
ZnI <sub>2</sub> .4NH <sub>3</sub>	c	695	93.6HI; &	(193, 339)
ZnI <sub>2</sub> .6NH <sub>3</sub>	c	878	dissoc.*	(193, 339)
Zn(NH <sub>4</sub> ) <sub>2</sub> (SO <sub>4</sub> ) <sub>2</sub> .2H <sub>2</sub> O	c	2735	dissoc.*	(262*)
Zn(NH <sub>4</sub> ) <sub>2</sub> (SO <sub>4</sub> ) <sub>2</sub> .6H <sub>2</sub> O	c	3962	-55	(334, 458)
ZnCO <sub>3</sub>	ppt.	809	ZnSO <sub>4</sub> + Na <sub>2</sub> CO <sub>3</sub>	(58)
ZnC <sub>2</sub> O <sub>4</sub> .2H <sub>2</sub> O	c	1562	ZnSO <sub>4</sub> + K <sub>2</sub> C <sub>2</sub> O <sub>4</sub>	(56)
Zn(C <sub>2</sub> H <sub>5</sub> ) <sub>2</sub>	liq.	31	326HCl; &	(467)
Zn(CHO <sub>2</sub> ) <sub>2</sub>	c	961	17 <sup>15</sup> <sub>500</sub>	(55)
	250	978	ZnSO <sub>4</sub> + NaCHO <sub>2</sub>	(55)
			-10 <sup>13</sup> <sub>500</sub>	(55)
Zn(CHO <sub>2</sub> ) <sub>2</sub> .2H <sub>2</sub> O	c	1560	41 <sup>13</sup> <sub>720</sub>	(55)
Zn(C <sub>2</sub> H <sub>5</sub> O <sub>2</sub> ) <sub>2</sub>	c	1093	Ba(C <sub>2</sub> H <sub>5</sub> O <sub>2</sub> ) <sub>2</sub> + ZnSO <sub>4</sub> ; &	(55, 976)
	400	1134.1	dil.	
	200	1130.4	dil.	
	100	1126.0	dil.	
	50	1120.9	dil.	
Zn(C <sub>2</sub> H <sub>5</sub> O <sub>2</sub> ) <sub>2</sub> .H <sub>2</sub> O	c	1392	29 <sup>13</sup> <sub>500</sub>	(55)
Zn(C <sub>2</sub> H <sub>5</sub> O <sub>2</sub> ) <sub>2</sub> .2H <sub>2</sub> O	c	1689	18 <sup>10</sup> <sub>500</sub>	(55)
Zn(CN) <sub>2</sub>	c	-68	14HCl	(152, 555)
3Zn(CN) <sub>2</sub> .ZnO	c	167	95HCl	(152, 555)
ZnSiO <sub>3</sub>	c	1199	358HF(30%)	(740)
Zn <sub>2</sub> SiO <sub>4</sub>	gla.	1450	416HF(30%)	(740)
	c	1487	379HF(30%)	(740)
ZnSn <sub>3</sub>	c	-25	+ Br	(511)
ZnSn <sub>4</sub>	c	-54	+ Br	(511)
ZnSn <sub>5</sub>	c	-17	+ Br	(511)
ZnSn <sub>6</sub>	c	-21	+ Br	(511)
<b>Cadmium*</b>				
Cd(α)	c	0	Def.	
Cd(β)	c	-0.23	α*	(443*)
	g	-112	→α*	(228, 329, 370, 657, 792, 881, 1069*)
Cd <sup>++</sup>	aq.	73	Cd(NO <sub>3</sub> ) <sub>2</sub>	(385)
CdO	c	273	Cd + O; &	(315, 715, 730.5)
Cd(OH) <sub>2</sub> (ordin. ppt.)	ppt.	559	CdSO <sub>4</sub> + KOH; &	(976)
CdF <sub>2</sub>	1200	721.9	CdCl <sub>2</sub> + AgF	(793)
CdCl <sub>2</sub>	c	389.2	13.0 <sup>18</sup> <sub>400</sub>	(197, 283, 552, 810, 858, 869, 871, 976)
	400	402.1	dil.	(976)
	200	401.3	dil.	
	100	400.6	dil.	
	50	400.1	dil.	
	20	397.6	dil.	
	10	390.7	dil.	(283, 976)
CdCl <sub>2</sub> .H <sub>2</sub> O	c	685.5	+2.6 <sup>18</sup> <sub>400</sub>	(810)
CdCl <sub>2</sub> .2H <sub>2</sub> O	c	1129.9	-12.3 <sup>18</sup> <sub>400</sub> ; &	(283, 339, 339*)
CdCl <sub>2</sub> .4H <sub>2</sub> O	c	1938	dissoc.*	(1020*)
CdCl <sub>2</sub> .2HCl.7H <sub>2</sub> O	c	2744	-10 <sup>11</sup> <sub>15</sub>	(100)
CdCl <sub>2</sub> .CdO.H <sub>2</sub> O	c	988	56 <sup>15</sup> <sub>HCl</sub>	(966)
CdBr <sub>2</sub>	c	317.2	1.8 <sup>18</sup> <sub>400</sub>	(976)
	400	319	Cd + Br; &	(511, 754, 976)
CdBr <sub>2</sub> .4H <sub>2</sub> O	c	1494.1	-30.5 <sup>18</sup> <sub>500</sub>	(976)
CdBr <sub>2</sub> .CdO.H <sub>2</sub> O	c	911	60.0 <sup>15</sup> <sub>HBr</sub>	(966)
CdI <sub>2</sub>	c	202.5	Cd + I <sub>2</sub> ; &	(284, 339*)
	400	198.5	-4.0 <sup>18</sup> <sub>400</sub>	(284, 291, 976)

\* Cd(ClO<sub>3</sub>)<sub>2</sub>.6NH<sub>3</sub>, Cd(ClO<sub>3</sub>)<sub>2</sub>.4NH<sub>3</sub>, Cd(IO<sub>3</sub>)<sub>2</sub>.4NH<sub>3</sub>; heat of dissoc. (341\*). Alloys with Pb, Sn (955).



Formula	State	Q, kj	Method	Lit.
<b>Cadmium.—(Continued)</b>				
CdI <sub>2</sub> .CdO.H <sub>2</sub> O	c	756	108.2 <sup>13</sup> <sub>HI</sub>	(966)
CdS	c	142	+Na <sub>2</sub> O <sub>2</sub>	(715)
	ppt.	145	CdSO <sub>4</sub> + Na <sub>2</sub> S	(976)
CdSO <sub>4</sub>	c	912.0	44.7 <sup>13</sup> <sub>400</sub> ; & dil.	(2900)
	400	956.72		(290, 525)
	200	955.9	+BaCl <sub>2</sub> ; & dil.	(976)
	100	955.24		(525†)
	50	954.40	dil.	
	30.6	952.20	dil.	
	20.6	950.81	dil.	
	15.6	948.86	dil.	
	13.6	945.37	dil.	
CdSO <sub>4</sub> .2.67H <sub>2</sub> O	c	1709.2	10.6 <sup>18</sup> <sub>400</sub>	(525, 544,* 941†)
CdS <sub>2</sub> O <sub>8</sub>	aq.	1221	BaS <sub>2</sub> O <sub>8</sub> + CdSO <sub>4</sub>	(976)
CdSe	ppt.	90 (7)	CdSO <sub>4</sub> + Na <sub>2</sub> Se	(359)
	c	70	+Br	(359)
CdTe	c	66	+Br	(351)
CdN <sub>2</sub>	c	445	dissoc.	(1113)
Cd(NO <sub>3</sub> ) <sub>2</sub>	400	489.9	CdSO <sub>4</sub> + Ba(NO <sub>3</sub> ) <sub>2</sub>	(976)
Cd(NO <sub>3</sub> ) <sub>2</sub> .H <sub>2</sub> O	c	758.6	17.5 <sup>18</sup> <sub>400</sub>	(976)
Cd(NO <sub>3</sub> ) <sub>2</sub> .4H <sub>2</sub> O	c	1655.7	-21.1 <sup>19</sup> <sub>400</sub>	(976)
CdCl <sub>2</sub> .NH <sub>3</sub>	c	510	dissoc.*	(1081*)
CdCl <sub>2</sub> .2NH <sub>3</sub>	c	630	35.8 <sup>16</sup> <sub>HCl</sub>	(966, 1081*)
CdCl <sub>2</sub> .4NH <sub>3</sub>	c	806	dissoc.*	(1081*)
CdCl <sub>2</sub> .4NH <sub>3</sub> .Cl	c	1651	-57.5 <sup>15</sup>	(966)
CdCl <sub>2</sub> .6NH <sub>3</sub>	c	991	dissoc.*	(324,* 1081*)
CdCl <sub>2</sub> .10NH <sub>3</sub>	c	1292	dissoc.*	(1081*)
2CdCl <sub>2</sub> .2NH <sub>3</sub> .Cl.H <sub>2</sub> O	c	1729	-44.9 <sup>16</sup>	(966, 1081)
CdBr <sub>2</sub> .NH <sub>3</sub>	c	438	dissoc.*	(1081*)
CdBr <sub>2</sub> .2NH <sub>3</sub>	c	552	32.5 <sup>15</sup> <sub>HBr</sub>	(966, 1081)
CdBr <sub>2</sub> .6NH <sub>3</sub>	c	917	dissoc.*	(332*)
CdBr <sub>2</sub> .12NH <sub>3</sub>	c	1383	dissoc.*	(1081*)
2CdBr <sub>2</sub> .2NH <sub>3</sub> .Br.H <sub>2</sub> O	c	1485	-60 <sup>16</sup>	(966)
CdI <sub>2</sub> .2NH <sub>3</sub>	c	410	50 <sup>15</sup> <sub>HI</sub> ; & dil.	(966*)
CdI <sub>2</sub> .6NH <sub>3</sub>	c	779	dissoc.*	(332*)
2CdI <sub>2</sub> .2NH <sub>3</sub> .H <sub>2</sub> O	c	1126	-66.0 <sup>15</sup>	(966)
CdSO <sub>4</sub> .4NH <sub>3</sub>	c	1307	dissoc.*	(335*)
CdSO <sub>4</sub> .6NH <sub>3</sub>	c	1497	dissoc.*	(335,* 538*)
CdSb	c	11	+Br <sub>2</sub>	(186)
CdSb <sub>2</sub>	c	17	+Br <sub>2</sub>	(186)
CdCO <sub>3</sub>	ppt.	748	CdSO <sub>4</sub> + Na <sub>2</sub> CO <sub>3</sub> ; & 35 <sup>20</sup> <sub>H<sub>2</sub>SO<sub>4</sub></sub> ; & dil.	(976)
Cd(CN) <sub>2</sub>	c	154	dissoc.	(1113)
Cd(ONC) <sub>2</sub>	c	151	53 <sup>18</sup> <sub>H<sub>2</sub>SO<sub>4</sub></sub> ; & dil.	(555)
Cd(CN) <sub>2</sub> .CdO.5H <sub>2</sub> O	c	1955	+Br <sub>2</sub>	(511)
CdZn(0.35)	c	15	+Br <sub>2</sub>	(511)
CdZn(1.25)	c	29	+Br <sub>2</sub>	(511)
CdZn(4.41)	c	25	+Br <sub>2</sub>	(511)

<b>Mercury*</b>				
Hg	liq.	0	Def.	(460.5, 584.5, 599.5, 792.5)
Hg <sup>++</sup>	gas	-60.2	→liq.	
Hg <sup>++</sup>	aq.	-174	Hg(NO <sub>3</sub> ) <sub>2</sub>	
Hg <sub>2</sub>	aq.	-168	Hg <sub>2</sub> (NO <sub>3</sub> ) <sub>2</sub>	
HgO (red)	c	91	+Hg <sub>2</sub> ; & dil.	(242, 1008)
HgO (yellow)	ppt.	87	HgCl <sub>2</sub> + KOH; & dil.	(108, 976)
Hg <sub>2</sub> O	c	90	Hg <sub>2</sub> Cl <sub>2</sub> + KOH; & dil.	(976, 1008)
HgCl <sub>2</sub>	c	223.6	-13.9 <sup>18</sup> <sub>300</sub>	(52, 511, 976)
Hg <sub>2</sub> Cl <sub>2</sub>	aq.	210	+KI; & dil.	(69, 976)
	ppt.	263.7	+KI; & dil.	(429,* 637,* 976, 1008, 1065*)
HgCl <sub>2</sub> .HgO	c	317	59 <sup>9</sup> <sub>HCl</sub>	(11, 12)
HgCl <sub>2</sub> .2HgO	c	409	131 <sup>11</sup> <sub>HCl</sub>	(11, 12)
HgCl <sub>2</sub> .3HgO	c	496	210 <sup>9</sup> <sub>HCl</sub>	(11, 12)
HgCl <sub>2</sub> .4HgO	c	583	289 <sup>9</sup> <sub>HCl</sub>	(11, 12)

<b>Mercury.—(Continued)</b>				
H <sub>2</sub> HgCl <sub>4</sub>	aq.	548	HCl + HgCl <sub>2</sub>	(754, 976, 1008)
HgBr <sub>2</sub>	c	174	Hg + Br <sub>2</sub> ; & dil.	(754, 976, 1008)
	aq.	156	-14 <sup>12</sup> <sub>KBr</sub>	(106)
Hg <sub>2</sub> Br <sub>2</sub>	ppt.	206	+Br <sub>2</sub> ; & dil.	(754, 976, 1008)
HgBr <sub>2</sub> .HgO	c	270	148.5 <sup>9</sup> <sub>HBr</sub>	(11, 12)
HgBr <sub>2</sub> .2HgO	c	360	291 <sup>9</sup> <sub>HBr</sub>	(11, 12)
HgBr <sub>2</sub> .3HgO	c	453	430.5 <sup>9</sup> <sub>HBr</sub>	(11, 12)
HgBr <sub>2</sub> .4HgO (?)	c	524	572 <sup>9</sup> <sub>HBr</sub>	(11, 12)
H <sub>2</sub> HgBr <sub>4</sub>	1500	424	HgBr <sub>2</sub> + HBr	(107, 1011)
HgI <sub>2</sub> (red)	c	106	Hg + I + KI; & dil.	(1008)
HgI <sub>2</sub> (yellow)	c	93	Tr.; 13 <sup>18</sup> <sub>(red)</sub>	(107, 204)
Hg <sub>2</sub> I <sub>2</sub> (yellow)	c	120.8	+KI; & dil.	(1008)
Hg <sub>2</sub> I <sub>2</sub> (yellow-green)	ppt.	120.2	Tr.; 0.6 <sup>18</sup> <sub>(yellow)</sub> ; & dil.	(1008)
H <sub>2</sub> HgI <sub>4</sub>	aq.	357.1	HgI <sub>2</sub> + HI	(766, 1008)
HgS (red)	c	45.6	HgS (black)	(1008)
HgS (red)	amorp.	45.4	HgS (black)	(1008)
HgS (black)	amorp.	44	HgCl <sub>2</sub> + H <sub>2</sub> S	(60)
HgSO <sub>4</sub>	c	680	+HCl; & dil.	(1008)
	4H <sub>2</sub> SO <sub>4</sub> (100)	701	HgSO <sub>4</sub> + H <sub>2</sub> SO <sub>4</sub>	(1008)
Hg <sub>2</sub> SO <sub>4</sub>	c	718.1	+KI; & dil.	(292, 505, 1008)
3HgO.SO <sub>3</sub>	c	899	38H <sub>2</sub> SO <sub>4</sub> (100)	(1008)
HgSO <sub>4</sub> .2H <sub>2</sub> SO <sub>4</sub>	100	1566.6	HgSO <sub>4</sub> + H <sub>2</sub> SO <sub>4</sub>	(1008)
	200	1569.4	HgSO <sub>4</sub> + H <sub>2</sub> SO <sub>4</sub>	(1008)
HgSe	c	17	+Br	(350, 7869)
	ppt.	22	HgCl <sub>2</sub> + Na <sub>2</sub> Se	(350, 7869)
Hg <sub>2</sub> (N <sub>3</sub> ) <sub>2</sub>	c	-408	dissoc.	(176, 1113)
Hg(NO <sub>3</sub> ) <sub>2</sub>	aq.	243	+NaOH	(976)
Hg <sub>2</sub> (NO <sub>3</sub> ) <sub>2</sub>	aq.	249.0	Hg <sub>2</sub> (NO <sub>3</sub> ) <sub>2</sub> + KCl	(976)
Hg <sub>2</sub> (NO <sub>3</sub> ) <sub>2</sub>	HNO <sub>3</sub> (100)	245.6	Hg <sub>2</sub> (NO <sub>3</sub> ) <sub>2</sub> .2H <sub>2</sub> O + HNO <sub>3</sub> ; & dil.	(976, 1008)
Hg <sub>2</sub> (NO <sub>3</sub> ) <sub>2</sub> .2H <sub>2</sub> O	c	870	-52 <sup>18</sup> <sub>KI</sub>	(1008)
(Hg(NO <sub>3</sub> ) <sub>2</sub> ) <sub>2</sub> .H <sub>2</sub> O	c	782	-5.9 <sup>18</sup> <sub>HNO<sub>3</sub></sub> ; & dil.	(1008)
Hg(NO <sub>3</sub> ) <sub>2</sub> .2HgO.H <sub>2</sub> O	c	1029	16HNO <sub>3</sub> ; & dil.	(1008)
(Hg <sub>2</sub> N) <sub>2</sub> O	c	-322	632 <sup>18</sup> <sub>KCN</sub>	(435)
(Hg <sub>2</sub> N) <sub>2</sub> O.H <sub>2</sub> O	aq.	-307	+KCN	(435)
(Hg <sub>2</sub> N) <sub>2</sub> O.4H <sub>2</sub> O	c	-23	619 <sup>18</sup> <sub>KCN</sub>	(435)
(Hg <sub>2</sub> N) <sub>2</sub> O.5H <sub>2</sub> O	c	870	587 <sup>18</sup> <sub>KCN</sub>	(435)
(NH <sub>2</sub> Cl) <sub>2</sub> .H <sub>2</sub> O	c	1582	577 <sup>18</sup> <sub>KCN</sub>	(435)
(NH <sub>2</sub> Cl) <sub>2</sub> .H <sub>2</sub> O	c	230	N <sub>2</sub> H <sub>4</sub> O.4H <sub>2</sub> O + HCl	(435)
(NH <sub>2</sub> Cl) <sub>2</sub> .H <sub>2</sub> O	c	531	514 <sup>18</sup> <sub>KCN</sub>	(1081*)
HgCl <sub>2</sub> .2NH <sub>3</sub>	c	527	43HCl(a); & dil.	(1081*)
HgCl <sub>2</sub> .8NH <sub>3</sub>	c	932	dissoc.*	(1081*)
HgCl <sub>2</sub> .9 <sup>1</sup> / <sub>2</sub> NH <sub>3</sub>	c	1046	dissoc.*	(1081*)
Hg <sub>2</sub> Cl <sub>2</sub> .2NH <sub>3</sub>	c	475	dissoc.*	(222, 637)
NH <sub>2</sub> Cl.NH <sub>4</sub> Cl	c	592	228 <sup>18</sup> <sub>KCN</sub>	(435)
NH <sub>2</sub> Cl.3NH <sub>4</sub> Cl	c	1212	204 <sup>18</sup> <sub>KCN</sub>	(435)
(NH <sub>2</sub> Cl) <sub>2</sub> .NH <sub>3</sub>	c	47	508 <sup>18</sup> <sub>KCN</sub>	(435)
NH <sub>2</sub> Cl.NH <sub>3</sub>	c	66	dissoc.*	(435)
(NH <sub>2</sub> Cl) <sub>2</sub> .HgCl <sub>2</sub>	c	201	679 <sup>18</sup> <sub>KCN</sub>	(435)
HgBr <sub>2</sub> .2NH <sub>3</sub>	c	398	85 <sup>18</sup> <sub>KCN</sub> (10)	(1081*)
HgBr <sub>2</sub> .8NH <sub>3</sub>	c	817	dissoc.*	(1081*)
(NH <sub>4</sub> ) <sub>2</sub> .HgBr <sub>4</sub>	1500	670	NH <sub>4</sub> Br + HgBr <sub>2</sub>	(1012)
NH <sub>2</sub> Br	c	-62	253 <sup>18</sup> <sub>KCN</sub>	(435)
(NH <sub>2</sub> Br) <sub>2</sub> .HgBr <sub>2</sub>	c	91	+KCN	(435)
(NH <sub>2</sub> Br) <sub>4</sub> .HgBr <sub>2</sub>	c	-15	1097 <sup>18</sup> <sub>KCN</sub>	(435)
NH <sub>2</sub> Br.NH <sub>4</sub> Br	c	238	210 <sup>18</sup> <sub>KCN</sub>	(435)
NH <sub>2</sub> Br.3NH <sub>4</sub> Br	c	789	+KCN	(435)
HgI <sub>2</sub> . <sup>1</sup> / <sub>2</sub> NH <sub>3</sub>	c	181	dissoc.*	(1081*)
HgI <sub>2</sub> .2NH <sub>3</sub>	c	301	90 <sup>18</sup> <sub>KCN</sub> (10)	(1081*)
HgI <sub>2</sub> .8NH <sub>3</sub>	c	610	dissoc.*	(1081*)
HgCrO <sub>4</sub>	c	670	29.4 <sup>18</sup> <sub>HCl</sub> (100)	(114)
Hg(C <sub>2</sub> H <sub>3</sub> O <sub>2</sub> ) <sub>2</sub>	c	829	-17 <sup>15</sup> <sub>440</sub>	(114)
	aq.	812	HCl; & dil.	(114)

\* Amalgams, cf. other metals. Amalgams with Sn, Cd, Bi, Pb, v. (655). In (872), Tl (876, 873).



Formula	State	Q, kj	Method	Lit.	Formula	State	Q, kj	Method	Lit.
<b>Mercury.—(Continued)</b>					<b>Copper.—(Continued)</b>				
$\text{HgH}_2(\text{C}_2\text{H}_3\text{O}_2)_4$	aq.	1807	$\text{HC}_2\text{H}_3\text{O}_2 + \text{Hg}(\text{C}_2\text{H}_3\text{O}_2)_2$	(114)	$\text{CuCl}_2$ —(Continued)	200	259.5	$\text{CuO} + \text{HCl}; \&$	(51, 91, 759,† 879, 976)
$\text{Hg}_2(\text{C}_2\text{H}_3\text{O}_2)_2$	c	851	+KI; &	(1008)		100	257.6	dil.	(51, 849,† 976)
$\text{Hg}(\text{C}_2\text{H}_3\text{O}_2)_2 \cdot \text{HgO}$	c	916	$\text{Hg}(\text{C}_2\text{H}_3\text{O}_2)_2 + \text{KOH}$	(1008)		50	254.6	dil.	
$\text{Hg}(\text{CN})_2$	c	-260	-13	(53, 976)		30	250.9	dil.	
$\text{Hg}(\text{CN})_4^{2-}$	aq.	-272	$\text{HgCl}_2 + \text{KCN}$	(108, 976)		20	247.5	dil.	
$\text{Hg}(\text{CN})_4$	aq.	-515	$\text{Na}_2\text{Hg}(\text{CN})_4$	(108, 976)	$\text{CuCl}_2 \cdot 2\text{H}_2\text{O}$	10	240.6	dil.	
$\text{Hg}(\text{C}_2\text{N}_2\text{O}_2)_2$	c	-270	dissoc.	(172, 1097, 1113)		c	816.2	$15.5^{18}_{200}$	(212,† 900, 976)
$\text{Hg}(\text{CN})_2 \cdot \text{HgO}$	c	-164	57HCl	(555)	$\text{Cu}(\text{ClO}_2)_2$	400	93	$\text{Ba}(\text{ClO}_2)_2 + \text{CuSO}_4$	(976)
$3\text{Hg}(\text{CN})_2 \cdot \text{HgO}$	c	-653	0.8HCl	(555)	$\text{CuCl}_2 \cdot 3\text{CuO}$	c	672	230HCl	(103)
$\text{Hg}(\text{CN})_2 \cdot \text{NH}_4\text{CN}$	400	-256	mix.	(1009)	$\text{HCuCl}_2$	550	439	$\text{CuCl}_2 + \text{HCl}$	(789)
$\text{Hg}(\text{CN})_2 \cdot 2\text{NH}_4\text{CN}$	600	-248	mix.	(1009)	$\text{CuCl}_2 \cdot 3\text{CuO} \cdot 4\text{H}_2\text{O}$ (atacamite)	c	1909	138HCl	(103)
$\text{Hg}(\text{CN})_2 \cdot \text{HgCl}_2$	c	-38	-23 <sup>14</sup>	(106)	$\text{CuBr}$	c	103	N; &	(215,* 976)
$\text{Hg}(\text{CN})_2 \cdot \text{NH}_4\text{Cl}$	aq.	-61	mix.	(106)	$\text{CuBr}_2$	c	134	$34.5^{20}_{400}$	(901,* 976)
$\text{Hg}(\text{CN})_2 \cdot \text{NH}_4\text{Cl} \cdot \frac{1}{2}\text{H}_2\text{O}$	500	26	mix.	(1009)		c	168	$\text{CuSO}_4 + \text{BaBr}_2; \&$	(511, 876, 976)
$\text{Hg}(\text{CN})_2 \cdot \text{NH}_4\text{Br}$	500	-18	mix.	(1009)	$\text{CuBr}_2 \cdot 4\text{H}_2\text{O}$	c	1319	-6	(901)
$\text{Hg}(\text{CN})_2 \cdot \text{NH}_4\text{Br} \cdot \text{H}_2\text{O}$	c	312	-43.9	(1009)	$\text{CuBr}_2 \cdot 3\text{Cu}(\text{OH})_2$	c	1532	136HBr	(901)
$\text{Hg}(\text{CN})_2 \cdot \text{NH}_4\text{I}$	500	-75	mix.	(1009)	$\text{CuI}$	c	66	$\text{CuSO}_4 + \text{KI}; \&$	(91, 215,* 976)
$\text{Hg}(\text{CN})_2 \cdot \text{NH}_4\text{I} \cdot \frac{1}{2}\text{H}_2\text{O}$	c	48	-51.3	(1009)		c	13	+NH <sub>3</sub>	
$\text{Hg}(\text{CNS})_2$	c	-211	$\text{HgCl}_2 + \text{KCNS}$	(555)	$\text{CuI}_2$	c	38	analogy	
$\text{HgSn}_2$	liq.		dil.*	(512, 873, 960)		aq.	48.6	ions	(976, 1027)
$\text{Hg}_{100}\text{Pb}$	liq.	-11.3	$\text{Hg} + \text{Pb}^*$	(637)	$\text{CuS}$	c		$\text{Cu} + \text{S}$	(45.5)
$\text{Hg}_{100}\text{Pb}$	liq.	-10.5	dil.*	(562,* 960)	$\text{Cu}_2\text{S(I)}$	c	79.4	Tr.; 3.8 <sup>103</sup> <sub>(II)</sub>	(4,* 60, 830,* 1027)
$\text{Hg}_{100}\text{Pb}$	liq.	-11.0	dil.*	(562)	$\text{Cu}_2\text{S(II)}$	c		$\text{Cu} + \text{S}$	(360.5, 458, 810,* 910, 976, 1055*)
$\text{Hg}_{100}\text{Pb}$	liq.	-11	dil.*	(562)	$\text{CuSO}_4$	c	748.0	$66.5^{18}_{800}; \&$	
$\text{HgPb}_2$	c	-0.2	$\text{Hg} + \text{Pb}^*$	(241,* 439,* 505*)		800	814.6	dil.	(51, 976)
$\text{Hg}_{100}\text{Zn}$	liq.	-9.4	$\text{Zn} + \text{Hg}^*$	(562*)		200	814.4	$\text{CuCl}_2 + \text{H}_2\text{SO}_4; \&$	
$\text{Hg}_{100}\text{Zn}$	liq.	-9.7	dil.	(562*)		100	814.1	dil.	(976)
$\text{HgBr}_2 \cdot \text{ZnBr}_2$	4400	556	mix.	(1012)	$\text{CuSO}_4 \cdot \text{H}_2\text{O}$	60	813.9	dil.	(976)
$2\text{HgBr}_2 \cdot \text{ZnBr}_2$	8400	713	mix.	(1012)		c	1061.6	$39.1^{18}_{800}$	(320,* 458, 910, 920, 976)
$\text{HgBr}_2 \cdot 2\text{ZnBr}_2$	4800	957	mix.	(1012)	$\text{CuSO}_4 \cdot 3\text{H}_2\text{O}$	c	1281	+H <sub>2</sub> O;* &	(781*)
$\text{Hg}(\text{CN})_2 \cdot \text{ZnCl}_2$	1000	-60	mix.	(1009)	$\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$	c	2257.1	-11.7 <sup>18</sup> <sub>800}; &amp;</sub>	(320, 360.5, 429,* 458, 530,* 810, 909, 976)
$\text{Hg}(\text{CN})_2 \cdot \text{ZnCl}_2 \cdot 7\text{H}_2\text{O}$	c	1999	-56.0 <sup>16</sup>	(1009)		c	726	88	(544)
$\text{Hg}(\text{CN})_2 \cdot \text{ZnBr}_2$	1000	-150	mix.	(1009)	$\text{Cu}_2\text{SO}_4$	aq.	1071	ions	(976)
$\text{Hg}(\text{CN})_2 \cdot \text{ZnBr}_2 \cdot 8\text{H}_2\text{O}$	c	2226	-87 <sup>16</sup>	(1009)	$\text{Cu}_2\text{O}_4$	c	2523	-20.5 <sup>18</sup> <sub>400}</sub>	(976)
$\text{Hg}_{100}\text{Cd}$	liq.	2.1	$\text{Cd} + \text{Hg}^*$	(562,* 960)	$\text{CuSO}_4 \cdot \text{CuO}$	c	920	+CuO*; &	(550*)
$\text{HgCd}$ (10% amalgam)	c	-23.7	$\text{Cd} + \text{Hg}^*$	(442,* 534*)	$\text{CuSO}_4 \cdot 3\text{CuO} \cdot 4\text{H}_2\text{O}$	c	1581	201H <sub>2</sub> SO <sub>4</sub>	(902)
$\text{HgBr}_2 \cdot \text{CdBr}_2$	4400	485	mix.	(1012)	$\text{CuSe}$	ppt.	20	$\text{Cu}(\text{C}_2\text{H}_3\text{O}_2)_2 + \text{H}_2\text{Se}$	(350)
$2\text{HgBr}_2 \cdot \text{CdBr}_2$	8400	640	mix.	(1012)	$\text{Cu}_2\text{Se(I)}$	c		Tr.; 4.7 <sup>110</sup> <sub>(II)</sub>	(45.5)
$\text{HgBr}_2 \cdot 2\text{CdBr}_2$	4800	809	mix.	(1012)	$\text{Cu}_2\text{Se(II)}$	c	31	+Br	(350)
$\text{Hg}(\text{CN})_2 \cdot \text{CdCl}_2$	600	131	mix.	(1009)	$\text{CuSeO}_4$	400	538	+KOH	(696)
$\text{Hg}(\text{CN})_2 \cdot \text{CdCl}_2 \cdot 2\text{H}_2\text{O}$	c	742	-39 <sup>16</sup>	(1009)	$\text{CuSeO}_4 \cdot 5\text{H}_2\text{O}$	c	1980	-11.1	(696)
$\text{Hg}(\text{CN})_2 \cdot \text{CdBr}_2$	600	-49	mix.	(1009)	$\text{Cu}_2\text{Te}$	c	17	+Br	(351)
$2\text{Hg}(\text{CN})_2 \cdot \text{CdBr}_2$	1000	-223	mix.	(1009)	$\text{CuN}_2$	c	-238	dissoc.	(1113)
$\text{Hg}(\text{CN})_2 \cdot \text{CdBr}_2 \cdot 3\text{H}_2\text{O}$	c	933	-52 <sup>14</sup>	(1009)	$\text{Cu}(\text{NO}_2)_2$	c	303	43.8 <sup>8</sup> <sub>280}</sub>	(482)
$2\text{Hg}(\text{CN})_2 \cdot \text{CdI}_2$	100	-339	mix.	(1009)		200	346.5	$\text{Ba}(\text{NO}_2)_2 + \text{CuSO}_4; \&$	(410, 976)
$2\text{Hg}(\text{CN})_2 \cdot \text{CdI}_2 \cdot 8\text{H}_2\text{O}$	c	2043	-93 <sup>16</sup>	(1009)		100	346.7	dil.	(51, 432, 976)
<b>Copper*</b>						50	347.2	dil.	
$\text{Cu}$	c	0	Def.			20	347.4	dil.	
$\text{Cu}^{++}$	400	-69	$\text{CuCl}_2$			15	346.6	dil.	
$\text{CuO}$	c	146	$\text{H}_2\text{SO}_4; \&$	(16, 410, 557, 713, 902, 976, 992,* 1055*)		12	345.4	dil.	
$\text{Cu}_2\text{O}$	c	167	dissoc.;* &	(16, 322, 874,* 976, 992*)	$\text{Cu}(\text{NO}_2)_2 \cdot 3\text{H}_2\text{O}$	c	1216	-10 <sup>18</sup>	(902)
$\text{Cu}(\text{OH})_2$ (blue)	ppt.	438.2	+H <sub>2</sub> SO <sub>4</sub> ; &	(410, 976)	$\text{Cu}(\text{NO}_2)_2 \cdot 6\text{H}_2\text{O}$	c	2108.4	-44.8 <sup>18</sup> <sub>400}</sub>	(902, 976)
$\text{Cu}(\text{OH})_2$ (green)	ppt.	439.3	60.5 <sup>18</sup> <sub>HNO<sub>3</sub></sub>	(410, 902)	$\text{Cu}(\text{NO}_2)_2 \cdot 3\text{CuO} \cdot 3\text{H}_2\text{O}$	c	1711	142HNO <sub>3</sub>	(902)
$3\text{CuO} \cdot \text{H}_2\text{O}$ (brown)	ppt.	730	66.0 <sup>18</sup> <sub>HNO<sub>3</sub></sub>	(410, 902)	$[\text{Cu}_4\text{NH}_3]^{++}$	400	329	$\text{CuSO}_4 + \text{NH}_3; \&$	(324)
$\text{CuF}_2$	400	585	$\text{CuCl}_2 + \text{AgF}$	(792)		500	501	$\text{CuSO}_4 + \text{NH}_3; \&$	(324)
$\text{CuCl}$	c	136	$\text{Cu}_2\text{O} + \text{HCl}; \&$	(215,* 328,* 552,* 759,* 780, 976)					
	HCl	109	-27.0 <sup>25</sup> <sub>HCl</sub>	(91, 759, 780)					
$\text{CuCl}_2$	c	215.2	46.5 <sup>18</sup> <sub>800}</sub>	(900, 976)					
	800	262.0	dil.						
	400	261.6	dil.						

\*  $\text{CuTi}_2(\text{SO}_4)_2 \cdot 6\text{H}_2\text{O}$ , heat of dissociation (261). Heat of dissociation of amines of  $\text{Cu}(\text{IO}_3)_2$ ;  $\text{Cu}_2\text{O}_4$ ;  $\text{Cu}(\text{CNS})_2$ ;  $\text{Cu}(\text{ClO}_2)_2$ ;  $\text{Cu}(\text{NO}_2)_2$ ;  $\text{Cu}_2\text{O}_4$ ;  $\text{Cu}(\text{ClO}_4)_2$ ;  $\text{Cu}_2\text{O}_4$ ;  $\text{Cu}(\text{HCO}_3)_2$ ;  $\text{Cu}(\text{C}_2\text{H}_3\text{O}_2)_2$  (240). Alloys with Cd, Ag (913).



Formula	State	Q. kj	Method	Lit.
<b>Copper.—(Continued)</b>				
[Cu.8NH <sub>3</sub> ] <sup>++</sup>	600	667	CuSO <sub>4</sub> + NH <sub>3</sub> ; &	(224)
[Cu.12NH <sub>3</sub> ] <sup>++</sup>	900	995	CuSO <sub>4</sub> + NH <sub>3</sub> ; &	(224)
CuO.28NH <sub>3</sub>	3000	245.2	Cu(OH) <sub>2</sub> + NH <sub>3</sub> ; &	(224)
	1500	245.1	dil.	
	500	244.7	dil.	
CuCl.NH <sub>3</sub>	c	251.1	dissoc.*	(196,* 650*)
CuCl <sub>2</sub> .2NH <sub>3</sub>	c	493	33.3HCl; &	(224, 1080*)
CuCl <sub>2</sub> .2NH <sub>4</sub> Cl	c	827	20 <sup>15</sup> <sub>650</sub>	(224)
CuCl <sub>2</sub> .2NH <sub>3</sub> . $\frac{1}{2}$ H <sub>2</sub> O	c	561	11 <sub>12</sub> NH <sub>3</sub>	(224)
CuCl <sub>2</sub> .5NH <sub>3</sub>	c	793	dissoc.*	(1080*)
CuCl <sub>2</sub> .2NH <sub>4</sub> Cl.2H <sub>2</sub> O	c	1393	-26	(224)
CuCl <sub>2</sub> .3NH <sub>3</sub>	c	428	dissoc.*	(196,* 650*)
CuCl <sub>2</sub> .3 $\frac{1}{2}$ NH <sub>3</sub>	c	632	-23NH <sub>3</sub>	(224, 335*)
CuCl <sub>2</sub> .4NH <sub>3</sub>	aq.	660	mix.	(224)
CuCl <sub>2</sub> .4NH <sub>3</sub> .2H <sub>2</sub> O	c	1293	-52 <sub>2</sub> NH <sub>3</sub>	(224)
CuCl <sub>2</sub> .5NH <sub>3</sub> . $\frac{1}{2}$ H <sub>2</sub> O	c	929	-39	(224)
CuCl <sub>2</sub> .5NH <sub>3</sub> .1 $\frac{1}{2}$ H <sub>2</sub> O	c	1217	-40	(224)
CuCl <sub>2</sub> .6NH <sub>3</sub>	aq.	832	mix.	(224)
CuCl <sub>2</sub> .10NH <sub>3</sub>	c	182	dissoc.*	(1080*)
2CuCl <sub>3</sub> .3NH <sub>3</sub>	c	601	dissoc.*	(196,* 650)
CuBr.NH <sub>3</sub>	c	210	dissoc.*	(196*)
CuBr <sub>2</sub> .2NH <sub>3</sub>	c	402	20HCl(20)	(1080*)
CuBr <sub>2</sub> .3NH <sub>3</sub>	c	389	dissoc.*	(196,* 650)
CuBr <sub>2</sub> .3 $\frac{1}{2}$ NH <sub>3</sub>	c	550	dissoc.*	(1080*)
CuBr <sub>2</sub> .5NH <sub>3</sub>	c	716	dissoc.*	(1080*)
CuBr <sub>2</sub> .10NH <sub>3</sub>	c	1108	dissoc.*	(1080*)
2CuBr <sub>3</sub> .3NH <sub>3</sub>	c	521	dissoc.*	(196,* 650)
CuI. $\frac{1}{2}$ NH <sub>3</sub>	c	122	dissoc.*	(196*)
CuI.NH <sub>3</sub>	c	176	dissoc.*	(196*)
CuI.2NH <sub>3</sub>	c	268	dissoc.*	(196,* 650)
CuI.3NH <sub>3</sub>	c	358	dissoc.*	(196,* 650)
CuI <sub>2</sub> .2NH <sub>3</sub>	c	277	+NH <sub>3</sub> *	(1080*)
CuI <sub>2</sub> .3 $\frac{1}{2}$ NH <sub>3</sub>	c	420	+Br <sup>-</sup>	(1080)
CuI <sub>2</sub> .5NH <sub>3</sub>	c	591	dissoc.*	(1080*)
CuI <sub>2</sub> .10NH <sub>3</sub>	c	963	dissoc.*	(1080*)
CuSO <sub>4</sub> .NH <sub>3</sub>	c	891	92 $\pi$ NH <sub>3</sub>	(224)
CuSO <sub>4</sub> .2NH <sub>3</sub>	c	1018	46 $\pi$ NH <sub>3</sub>	(224)
CuSO <sub>4</sub> .(NH <sub>4</sub> ) <sub>2</sub> SO <sub>4</sub>	c	1925	41.2 <sup>14</sup>	(224)
CuSO <sub>4</sub> .(NH <sub>4</sub> ) <sub>2</sub> SO <sub>4</sub> .2H <sub>2</sub> O	c	2493	dissoc.*	(261*)
CuSO <sub>4</sub> .(NH <sub>4</sub> ) <sub>2</sub> SO <sub>4</sub> .6H <sub>2</sub> O	c	3728	-44.4	(355, 455)
CuSO <sub>4</sub> .4NH <sub>3</sub>	c	1235	-7.6 $\pi$ NH <sub>3</sub> ; &	(224, 335*)
	aq.	1215	mix.	(224)
CuSO <sub>4</sub> .4NH <sub>3</sub> .1.5H <sub>2</sub> O	c	1682	30NH <sub>3</sub>	(224)
CuSO <sub>4</sub> .5NH <sub>3</sub>	c	1343	dissoc.*	(335*)
CuSO <sub>4</sub> .6NH <sub>3</sub> (?)	c	1346	+NH <sub>3</sub>	(224)
CuSO <sub>4</sub> .6NH <sub>3</sub>	aq.	1386	mix.	(224)
CuSO <sub>4</sub> .8NH <sub>3</sub>	aq.	1551	mix.	(224)
CuSO <sub>4</sub> .12NH <sub>3</sub>	aq.	1879	mix.	(224)
Cu <sub>2</sub> Sb	c	10	+Br <sub>2</sub>	(186)
CuCO <sub>3</sub>	ppt.	592	CuSO <sub>4</sub> + K <sub>2</sub> CO <sub>3</sub>	(58)
			2.2 <sup>15</sup> <sub>600</sub>	(55)
Cu(CHO <sub>2</sub> ) <sub>2</sub>	c	751	N	(55)
Cu(CHO <sub>2</sub> ) <sub>2</sub> .4H <sub>2</sub> O	c	1930	-33 <sup>10</sup> <sub>600</sub>	(55)
Cu(C <sub>2</sub> H <sub>3</sub> O <sub>2</sub> ) <sub>2</sub>	c	898	10 <sup>15</sup> <sub>320</sub>	(55)
	aq.	908	+Ba(OH) <sub>2</sub>	(976)
Cu(C <sub>2</sub> H <sub>3</sub> O <sub>2</sub> ) <sub>2</sub> .H <sub>2</sub> O	c	1193	0.7 <sup>15</sup> <sub>400</sub>	(55, 976)
CuCl <sub>2</sub> .CO.2H <sub>2</sub> O	c	1000(?)	CuCl + HCl + CO	(495)
Cu(C <sub>2</sub> H <sub>3</sub> SO <sub>4</sub> ) <sub>2</sub>	aq.	1785	Ba(C <sub>2</sub> H <sub>3</sub> SO <sub>4</sub> ) <sub>2</sub> + CuSO <sub>4</sub>	(976)
CuCN	c	-117	Hg(CN) <sub>2</sub> + CuI	(1007)
CuONC	c	-99	dissoc.	(1113)
Cu <sub>2</sub> Sn	c	33	+Br	(181, 511)
Cu <sub>2</sub> Zn	c	67	+Br	(28, 181, 432, 511)
Cu <sub>2</sub> Cd	c	12	+Br	(181, 186)
<b>Silver</b>				
Ag	c	0	Def.	
Ag(ppt. by Cu)	ppt.	-4(?)	+Hg	(141)

\* For heat of solution of various silver salts of organic acids, v. (600, 659); organic amines of silver (561); alloys with Cd (913). Amines with AgBrO<sub>3</sub>, AgClO<sub>3</sub>, AgNO<sub>3</sub>, AgMnO<sub>4</sub> (337).

Formula	State	Q. kj	Method	Lit.
<b>Silver.—(Continued)</b>				
Ag <sup>+</sup>	$\infty$	104	AgNO <sub>3</sub>	
Ag <sub>2</sub> O	c	29.1	dissoc.* &	(11, 144, 146, 581,* 641.1,* 713, 976)
Ag <sub>2</sub> O <sub>2</sub>	c	22.6	+HClO <sub>4</sub> ; &	(1094)
AgF	c	203.8	18.0 <sup>10</sup>	(481)
AgF(red)	amorp.	203.8	18 <sup>16</sup>	(481)
	400	221.8	+HCl; &	(408, 793)
AgF.H <sub>2</sub> O	c	504.3	3.6 <sup>10</sup>	(481)
AgF.2H <sub>2</sub> O	c	800.4	-6 <sup>10</sup>	(481)
AgF.4H <sub>2</sub> O	c	1387.1	-20.6 <sup>13</sup>	(464, 481)
Ag <sub>2</sub> F	c	210.5	11.5	(468)
AgF.HF	aq.	546.6	mix.	(464)
AgCl	ppt.	126.6	+Hg;* &	(110, 230, 367, 439,* 494,* 594, 635,* 760,* 1065*)
			+PbCl <sub>2</sub> *	(239,* 552,* 572,* 594,* 587, 1065*)
	aq.	68	conductivity*	(695*)
Ag <sub>2</sub> Cl (?)	c	130	+KCN	(470)
AgClO <sub>3</sub>	c	7	-31.5	(371)
AgClO <sub>4</sub>	aq.	-24	ions; &	(380)
	c	51.2	9.1	(253)
AgBr	aq.	60.3	+HCl; &	(1094)
	c	99.8	Ag + Br; &	(58, 572,* 584,* 594,* 976, 1036)
AgI(I)			Tr.; 5.32 <sup>147</sup> <sub>(II)</sub>	(45.2, 660, 1084)
AgI(II)	ppt.	62.5	Ag + I; &	(230, 367, 439,* 442,* 570,* 584, 594,* 967,* 968, 1036)
3AgI.HI.7H <sub>2</sub> O	c	2256	-9	(100)
Ag <sub>2</sub> S(I)	c		Tr.; 4.0 <sup>175</sup> <sub>(II)</sub>	(481, 553, 786*)
Ag <sub>2</sub> S(II)	c	21	AgNO <sub>3</sub> + H <sub>2</sub> S; &	(62, 362,* 976)
Ag <sub>2</sub> SO <sub>4</sub>	c	695	+KOH; &	(146, 668,* 976)
	aq.	676	+KOH; &	(976)
Ag <sub>2</sub> S <sub>2</sub> O <sub>8</sub> (?)	c	(?)		(369)
Ag(S <sub>2</sub> O <sub>3</sub> ) <sub>2</sub> <sup>++</sup>	aq.	1159	Na <sub>2</sub> Ag(S <sub>2</sub> O <sub>3</sub> ) <sub>2</sub>	(369)
Ag <sub>2</sub> S <sub>2</sub> O <sub>4</sub>	aq.	938	ions	(976)
Ag <sub>2</sub> S <sub>2</sub> O <sub>4</sub> .2H <sub>2</sub> O	c	967	-43.4 <sup>15</sup> <sub>400</sub>	(976)
AgSe	ppt.	-4.0	AgC <sub>2</sub> H <sub>3</sub> O <sub>2</sub> + H <sub>2</sub> Se	(350, 786*)
Ag <sub>2</sub> Se(I)	c		Tr.; 6.9 <sup>123</sup> <sub>(II)</sub>	(45.5)
Ag <sub>2</sub> Se(II)	c	4.0	+Br <sub>2</sub>	(350)
Ag <sub>2</sub> SeO <sub>4</sub>	c	401	AgNO <sub>3</sub> + K <sub>2</sub> SeO <sub>4</sub>	(606)
AgN <sub>3</sub>	c	-277	dissoc.	(1113)
AgNO <sub>2</sub>	c	53	-37	(55, 71)
	aq.	15	ions	(55, 71)
AgNO <sub>3</sub> (I)	c		Tr.; 2.4 <sup>160</sup> <sub>(II)</sub>	(2349)
AgNO <sub>3</sub> (II)	c	126	-22.9 <sup>15</sup> <sub>400</sub> ; &	(795, 976)
AgNO <sub>3</sub>	400	103.2	+HCl; &	(58, 124, 546,* 734, 782,* 976)
Ag <sub>2</sub> N <sub>2</sub> O <sub>2</sub>	c	-122	N	(169)
Ag(NH <sub>3</sub> ) <sub>2</sub> <sup>+</sup>	aq.	104	AgClO <sub>4</sub> .2NH <sub>3</sub>	(337)
AgNO <sub>2</sub> .NH <sub>3</sub>	c	251	dissoc.*	(154, 253, 327,* 554)
AgNO <sub>3</sub> .2NH <sub>3</sub>	c	358	-37.9	(154, 253, 554, 561, 626)
	aq.	320	ions; &	(253, 337,* 554, 566)
AgNO <sub>3</sub> .3NH <sub>3</sub>	c	444	-43.7	(253)
	aq.	401	AgNO <sub>3</sub> + NH <sub>3</sub> ; &	(154)
Ag(NH <sub>3</sub> ) <sub>2</sub> OH	aq.	829	Ag <sub>2</sub> O + NH <sub>3</sub>	(198)
AgCl.NH <sub>3</sub>	c	224	dissoc.*	(198)
AgCl.1 $\frac{1}{2}$ NH <sub>3</sub>	c	271	dissoc.*; &	(198, 559)



Formula	State	Q, kj	Method	Lit.
<b>Silver.—(Continued)</b>				
AgCl.3NH <sub>3</sub> .....	c	405	dissoc.*; &	(195, 539)
AgClO <sub>4</sub> .2NH <sub>3</sub> .....	c	323	-44.8	(353)
	2000	277	+HCl	(353)
AgClO <sub>4</sub> .3NH <sub>3</sub> .....	c	406	-46.8	(353)
	3000	359	+HCl	(353)
AgBr.NH <sub>3</sub> .....	c	190	dissoc.*	(195*)
AgBr.1½NH <sub>3</sub> .....	c	234	dissoc.*	(560*)
AgBr.3NH <sub>3</sub> .....	c	357	dissoc.*	(560*)
AgI.½NH <sub>3</sub> .....	c	110	dissoc.*; &	(195, * 560)
AgI.NH <sub>3</sub> .....	c	151	dissoc.*; &	(195*)
AgI.1½NH <sub>3</sub> .....	c	189	dissoc.*; &	(195*)
AgI.2NH <sub>3</sub> .....	c	226	dissoc.*; &	(195*)
AgI.3NH <sub>3</sub> .....	c	301	dissoc.*; &	(195*)
Ag <sub>2</sub> C <sub>2</sub> .....	c	-351	C <sub>2</sub> H <sub>2</sub> +	(153)
			AgNO <sub>3</sub> .2NH <sub>3</sub>	
Ag <sub>2</sub> CO <sub>3</sub> .....	c	506	AgNO <sub>3</sub> +	(55)
			K <sub>2</sub> CO <sub>3</sub> ; &	
	ppt.	490	AgNO <sub>3</sub> +	(55)
			K <sub>2</sub> CO <sub>3</sub> ; &	
Ag <sub>2</sub> C <sub>2</sub> O <sub>4</sub> .....	c	668	K <sub>2</sub> C <sub>2</sub> O <sub>4</sub> +	(56)
			AgNO <sub>3</sub>	
Ag <sub>2</sub> C <sub>2</sub> H <sub>4</sub> O <sub>4</sub> .....	c	1047	AgNO <sub>3</sub> +	(66)
			K <sub>2</sub> C <sub>2</sub> H <sub>4</sub> O <sub>4</sub>	
AgC <sub>2</sub> H <sub>3</sub> O <sub>3</sub> .....	c	406	-18.4	(55, 457, 600, 669†)
	aq.	388	N	(55)
Ag <sub>2</sub> C <sub>2</sub> .AgCl.....	c	-210	49	(162)
2Ag <sub>2</sub> C <sub>2</sub> .AgCl.....	c	547	97	(162)
Ag <sub>2</sub> C <sub>2</sub> .AgI.....	c	-215	53.18	(162)
			HCl	
Ag <sub>2</sub> C <sub>2</sub> .2AgI.....	c	-282	58.018	(162)
			HCl	
Ag <sub>2</sub> C <sub>2</sub> .Ag <sub>2</sub> SO <sub>4</sub> .....	c	357	C <sub>2</sub> H <sub>2</sub> +	(162)
			Ag <sub>2</sub> SO <sub>4</sub>	
2Ag <sub>2</sub> C <sub>2</sub> .Ag <sub>2</sub> SO <sub>4</sub> .....	c	57	164HCl	(162)
AgCN.....	c	-140	AgNO <sub>3</sub> +	(112, 976, 1011)
			KCN; &	
Ag(CN) <sub>2</sub> <sup>-</sup> .....	aq.	-245	KAg(CN) <sub>2</sub>	(976)
Ag(CN) <sub>3</sub> <sup>-</sup> .....	aq.	-403	K <sub>2</sub> Ag(CN) <sub>3</sub>	(976)
Ag <sub>2</sub> (CN) <sub>2</sub> .....	c	-209	80.6HCl; &	(626)
			dissoc.	(1112)
AgONC.....	c	-181	AgNO <sub>3</sub> +	(626)
AgCNO.....	c	99	KCNO	
Ag <sub>2</sub> C <sub>2</sub> .AgNO <sub>3</sub> .....	aq.	-205	Ag <sub>2</sub> C <sub>2</sub> +	(152)
			AgNO <sub>3</sub> ; &	
Ag <sub>2</sub> C <sub>2</sub> N <sub>2</sub> O <sub>3</sub> .....	c	374	Na <sub>2</sub> C <sub>2</sub> N <sub>2</sub> O <sub>3</sub> +	(626)
			NH <sub>3</sub> +	
			AgNO <sub>3</sub>	
AgCN.NH <sub>3</sub> .....	c	33	dissoc.*	(560*)
AgC <sub>2</sub> H <sub>3</sub> NH <sub>2</sub> <sup>+</sup> .....	aq.	148	Ag <sup>+</sup> +	(561)
			C <sub>2</sub> H <sub>3</sub> NH <sub>2</sub> <sup>-</sup>	
AgH <sub>2</sub> C <sub>2</sub> N <sub>2</sub> O <sub>3</sub> .....	c	600.6	AgNO <sub>3</sub> +	(626)
			NaH <sub>2</sub> C <sub>2</sub> N <sub>2</sub> O <sub>3</sub>	
AgCl.CH <sub>3</sub> NH <sub>2</sub> .....	c	209	dissoc.*	(550*)
AgBr.CH <sub>3</sub> NH <sub>2</sub> .....	c	182	dissoc.	(550*)
AgI.CH <sub>3</sub> NH <sub>2</sub> .....	c	151	dissoc.	(550*)
AgCNS.....	c	-88	AgNO <sub>3</sub> +	(555)
			HCNS	
	aq.	-177	-89*	(552)
AgSbOC <sub>2</sub> H <sub>4</sub> O <sub>4</sub> .....	c	1402	AgNO <sub>3</sub> +	(468)
			KSbOC <sub>2</sub> H <sub>4</sub> O <sub>4</sub>	
			H <sub>2</sub> O <sub>4</sub>	
Ag <sub>2</sub> Hg <sub>2</sub> .....	c	3.0	+Hg	(142, 649)
AgI.PbI <sub>2</sub> .....	c		Tr.; -10.7	(45.2)
AgI.CuI.....	c		Tr.; -12.5	(45.2)
AgI.2CuI.....	c		Tr.; -36.3	(45.2)

**Gold\***

Au(β).....	c	0	Def.	
Au(α) (from AuCl <sub>3</sub> + SO <sub>2</sub> ) (?)		15(?)	AuCl <sub>3</sub> +	(976)
			H <sub>2</sub> SO <sub>4</sub>	
Au <sub>2</sub> O <sub>3</sub> .....	c	-54	Na <sub>2</sub> O <sub>3</sub>	(713)
Au(OH) <sub>3</sub> .....	ppt.	418	+HCl aq.	(976)
AuCl.....	c	43	+HCl; &	(228, * 679, * 787, * 976)
AuCl <sub>3</sub> (?).....	c	79	+HCl	(796)

\* AgCuCl<sub>2</sub>, heat of dissociation (780.8).

Formula	State	Q, kj	Method	Lit.
<b>Gold.—(Continued)</b>				
AuCl <sub>3</sub> .....	c	113	+18.6 <sup>18</sup> <sub>900</sub>	(679, * 787, 798, * 976)
	aq.	132	+HBr	
AuCl <sub>4</sub> <sup>-</sup> .....	aq.	316	N = ½H <sub>2</sub> PtCl <sub>6</sub>	
AuCl <sub>3</sub> .2H <sub>2</sub> O.....	c	711	-7.1 <sup>18</sup> <sub>600</sub>	(976)
AuHCl <sub>4</sub> .....	aq.	316	AuCl <sub>3</sub> aq. +	(976)
			HCl	
AuHCl <sub>4</sub> .3H <sub>2</sub> O.....	c	1189	-14.9	(976)
AuHCl <sub>4</sub> .4H <sub>2</sub> O.....	c	1485	-24.4 <sup>18</sup> <sub>400</sub>	(976)
AuBr.....	c	19	+HBr; &	(668, 976)
AuBr <sub>2</sub> (?).....	c	34	+HBr	(796)
AuBr <sub>3</sub> .....	c	56	-15.7 <sup>18</sup> <sub>2000</sub>	(338, * 698, * 976)
	aq.	41	+HBr; &	(976)
AuBr <sub>4</sub> <sup>-</sup> .....	aq.	192	N =	
			½H <sub>2</sub> PtCl <sub>6</sub>	
AuHBr <sub>4</sub> .....	aq.	192	+SO <sub>2</sub> ; &	(976)
AuHBr <sub>4</sub> .5H <sub>2</sub> O.....	c	1872	-47.7 <sup>18</sup> <sub>1000</sub>	(976)
AuI.....	c	4	+H <sub>2</sub> SO <sub>4</sub> ; &	(976)
AuCl.NH <sub>3</sub> .....	c	192	122KCN(70)	(1078)
AuCl.2NH <sub>3</sub> .....	c	297	dissoc.*	(338*)
AuCl.6NH <sub>3</sub> .....	c	600	97KCN(70)	(1078*)
AuBr.NH <sub>3</sub> .....	c	155	103KCN(70)	(1078*)
AuBr.2NH <sub>3</sub> .....	c	256	93KCN(70)	(1078*)
AuBr.3NH <sub>3</sub> .....	c	337	dissoc.*	(1078*)
AuBr.4NH <sub>3</sub> .....	c	416	dissoc.*	(1078*)
AuBr.6NH <sub>3</sub> .....	c	575	dissoc.*	(1078*)
AuI.NH <sub>3</sub> .....	c	105	84KCN(70)	(1078*)
AuI.2NH <sub>3</sub> .....	c	190	dissoc.*	(1078*)
AuI.3NH <sub>3</sub> .....	c	282	dissoc.*	(1078*)
AuI.6NH <sub>3</sub> .....	c	521	dissoc.*	(1078*)
AuI.8NH <sub>3</sub> .....	c	614	dissoc.*	(1078*)
Au(CN) <sub>2</sub> <sup>-</sup> .....	aq.	-226	KAu(CN) <sub>2</sub>	
AuSn.....	Hg	50	Sn + AuHg	(960)
AuZn.....	Hg	60	Zn + AuHg	(960)
AuCd.....	Hg	40	Cd + AuHg	(960)
AuHg <sub>100</sub> .....	liq.	-8	Au + Hg	(960)

**Osmium**

Os.....	c	0	Def.	
OsO <sub>4</sub> .....	c	391	+O <sub>2</sub>	(1031)
	liq. <sup>40</sup>	376.8	→c <sup>40</sup>	(1031)
	gas	334	→c*	(1031*)

**Iridium**

Ir.....	c	0	Def.	
IrO <sub>3</sub> .....	c	21	dissoc.*	(1064*)
IrCl <sub>3</sub> .....	c	86	dissoc.*	(1059*)
	c	170	dissoc.*	(1059*)
IrCl <sub>3</sub> .....	c	253	dissoc.*	(1059*)

**Platinum**

Pt.....	c	0	Def.	
PtH (?).....	c	80	Pt + H <sub>2</sub>	(115, 356)
Pt(OH) <sub>2</sub> .....	ppt.	367	+HCHO <sub>2</sub>	(976)
PtCl.....	c	70	dissoc.*	(1060*)
PtCl <sub>2</sub> .....	c	150	dissoc.*	(1060*)
PtCl <sub>3</sub> .....	c	210	dissoc.*	(1060*)
PtCl <sub>4</sub> .....	c	262	104 <sup>11</sup> <sub>HCl(300)</sub>	(815, 1060*)
	aq.	343	+HCl	(815)
PtCl <sub>4</sub> <sup>-</sup> .....	aq.	511	K <sub>2</sub> PtCl <sub>6</sub>	
PtCl <sub>4</sub> .5H <sub>2</sub> O.....	c	1782	-7.7 <sup>18</sup> <sub>400</sub>	(815)
PtCl <sub>6</sub> <sup>-</sup> .....	aq.	693	K <sub>2</sub> PtCl <sub>6</sub>	
H <sub>2</sub> PtCl <sub>6</sub> .....	aq.	510	N = H <sub>2</sub> PtCl <sub>6</sub>	
H <sub>2</sub> PtCl <sub>6</sub> .....	aq.	693	+NaOH; &	(815, 976)
HPtCl <sub>6</sub> .2H <sub>2</sub> O.....	c	1040	60.0HCl	(815)
H <sub>2</sub> PtCl <sub>6</sub> .6H <sub>2</sub> O.....	c	2392	18.2 <sup>18</sup> <sub>600</sub>	(815)
PtBr <sub>4</sub> .....	c	168	41 <sup>1000</sup>	(815)
	aq.	209	+Co; &	(815)
PtBr <sub>4</sub> <sup>-</sup> .....	aq.	376	K <sub>2</sub> PtBr <sub>6</sub>	
PtBr <sub>6</sub> <sup>-</sup> .....	aq.	483	K <sub>2</sub> PtBr <sub>6</sub>	
H <sub>2</sub> PtBr <sub>6</sub> .....	aq.	483	N = H <sub>2</sub> PtCl <sub>6</sub>	
H <sub>2</sub> PtBr <sub>6</sub> .9H <sub>2</sub> O.....	c	3071	-12.0	(815)
PtI <sub>4</sub> .....	c	70	31NaI	(916)
PtI <sub>6</sub> <sup>-</sup> .....	aq.	218	Na <sub>2</sub> PtI <sub>6</sub>	



Formula	State	Q, kj	Method	Lit.
<b>Platinum.—(Continued)</b>				
Pt(NH <sub>3</sub> ) <sub>4</sub> <sup>2+</sup> .....	aq.	419	Pt(NH <sub>3</sub> ) <sub>4</sub> Cl <sub>2</sub>	
Pt(NH <sub>3</sub> ) <sub>4</sub> (OH) <sub>2</sub> .....	aq.	875	N	(976)
(NH <sub>3</sub> ) <sub>2</sub> PtCl <sub>4</sub> .....	c	812	-35.2	(976)
PtCl <sub>2</sub> .2NH <sub>3</sub> .....	aq.	777	ions	
PtCl <sub>2</sub> .4NH <sub>3</sub> .....	c	500	PtCl <sub>2</sub> + NH <sub>3</sub> ; &	(540)
PtCl <sub>2</sub> .4NH <sub>3</sub> .....	c	766	analogy	
PtCl <sub>2</sub> .4NH <sub>3</sub> .....	aq.	740	= PtCl <sub>2</sub> .4NH <sub>3</sub> .H <sub>2</sub> O	
PtCl <sub>2</sub> .4NH <sub>3</sub> .H <sub>2</sub> O.....	c	1071	-36.7	(976)
PtCl <sub>2</sub> .5NH <sub>3</sub> .....	c	855	dissoc.*	(343*)
PtI <sub>2</sub> .2NH <sub>3</sub> .....	c	Q		
PtI <sub>2</sub> .4NH <sub>3</sub> .....	c	226 + Q	dissoc.*	(343*)
PtI <sub>2</sub> .6NH <sub>3</sub> .....	c	396 + Q	dissoc.*	(343*)
Pt(NH <sub>3</sub> ) <sub>4</sub> SO <sub>4</sub> .....	aq.	1303.4	N	(976)
Ag <sub>2</sub> PtCl <sub>6</sub> .....	c	544	H <sub>2</sub> PtCl <sub>6</sub> + AgNO <sub>3</sub>	(818)
Ag <sub>2</sub> PtBr <sub>6</sub> .....	c	407	H <sub>2</sub> PtBr <sub>6</sub> + AgNO <sub>3</sub>	(818)

<b>Ruthenium</b>				
Ru.....	c	0	Def.	
RuO <sub>2</sub> .....	c	220	dissoc.*	(852*)
RuCl <sub>3</sub> .....	c	283	dissoc.*	(852, 1056*)

<b>Palladium</b>				
Pd.....	c	0	Def.	
PdO.....	c	90	dissoc.*	(1054*)
Pd <sub>2</sub> H.....	c	74.2	H <sub>2</sub> + Pd; &	(387, 448, 736*)
Pd(OH) <sub>2</sub> .....	ppt.	384	K <sub>2</sub> PdCl <sub>4</sub> + KOH; &	(556, 976)
Pd(OH) <sub>2</sub> .....	ppt.	703	K <sub>2</sub> PdCl <sub>4</sub> + KOH + KCl	(976)
PdCl <sub>2</sub> .....	c	182	KOH + KCl	(556, 976)
PdCl <sub>4</sub> <sup>2-</sup> .....	aq.	532	K <sub>2</sub> PdCl <sub>4</sub>	
PdCl <sub>6</sub> <sup>4-</sup> .....	aq.	707	K <sub>2</sub> PdCl <sub>6</sub>	
H <sub>2</sub> PdCl <sub>6</sub> .....	aq.	531	+ KOH	(976)
H <sub>2</sub> PdCl <sub>6</sub> .....	aq.	709	N = H <sub>2</sub> PtCl <sub>6</sub>	
PdBr <sub>2</sub> .....	c	117	Pd + Br; &	(886)
PdBr <sub>4</sub> <sup>2-</sup> .....	aq.	367	K <sub>2</sub> PdBr <sub>4</sub>	
PdI <sub>2</sub> .....	c	75	PdI <sub>2</sub> + H <sub>2</sub> O	analogy
PdI <sub>2</sub> .H <sub>2</sub> O.....	ppt.	374	K <sub>2</sub> PdCl <sub>4</sub> + KI; &	(556, 976)
PdCl <sub>2</sub> .2NH <sub>3</sub> .....	c	441	PdCl <sub>2</sub> + NH <sub>3</sub> ; &	(540)
PdCl <sub>2</sub> .4NH <sub>3</sub> .....	c	662	+ HCl; &	(540)
PdI <sub>2</sub> .2NH <sub>3</sub> .....	c	309	PdI <sub>2</sub> + NH <sub>3</sub>	(540)
PdI <sub>2</sub> .4NH <sub>3</sub> .....	c	509	+ HI; &	(540)
Pd(CN) <sub>2</sub> .....	c	-205	K <sub>2</sub> PdCl <sub>4</sub> + KCN; &	(886)

<b>Manganese*</b>				
Mn(α).....	c		Tr.; 5.5 <sup>1100</sup> (β)	(1069)
Mn(β).....	c	0	Def.	
Mn(from amalgam).....	amorp.	-15	+ HCl	(972)
Mn <sup>2+</sup> .....	aq.	208	MnCl <sub>2</sub>	
Mn <sup>3+</sup> .....	aq.	108	MnBr <sub>2</sub>	
MnO.....	c	386	+ O <sub>2</sub>	(619)
MnO <sub>2</sub> .....	c	525	dissoc.; &	(619)
MnO <sub>2</sub> .....	amorp.	506	+ Na <sub>2</sub> O <sub>2</sub>	(712)
MnO <sub>2</sub> (hydrated ppt.).....	amorp.	485	KMnO <sub>4</sub> + MnSO <sub>4</sub> ; &	(976)
Mn <sub>2</sub> O <sub>3</sub> .....	c	950	+ O <sub>2</sub> ; &	(699)
Mn <sub>2</sub> O <sub>4</sub> .....	aq.	516	KMnO <sub>4</sub>	
Mn <sub>2</sub> O <sub>4</sub> .....	c	1372	Mn + O	(619, 893)
HMnO <sub>4</sub> .....	aq.	516	N = HCl	(976)
Mn(OH) <sub>2</sub> .....	ppt.	684	MnSO <sub>4</sub> + KOH; &	(976)
Mn(OH) <sub>2</sub> .....	ppt.	920	MnF <sub>2</sub> + NaOH	(793)
MnF <sub>2</sub> .....	aq.	862	AgF + MnCl <sub>2</sub>	(793)
MnF <sub>3</sub> .....	aq.	1099	ions	
MnCl <sub>2</sub> .....	c	471.6	67.0 <sup>18</sup> (β)	(976)
	400	539	dil.	(976)
	100	537	Mn + HCl	(472, 976)

\* MnCl<sub>2</sub>(conc.) + nHCl(conc.) + Cl<sub>2</sub>(gas) = MnCl<sub>2</sub>.nHCl; ΔQ = 9.2 (99). MnCl<sub>2</sub>.2H<sub>2</sub>O, NH<sub>4</sub>Cl solid solutions, v. (371). Manganese salt amines (332, 335).

Formula	State	Q, kj	Method	Lit.
<b>Manganese.—(Continued)</b>				
MnCl <sub>2</sub> .2H <sub>2</sub> O.....	c	1076	34.3 <sup>300</sup>	(271, 999)
MnCl <sub>2</sub> .4H <sub>2</sub> O.....	c	1677	6.4 <sup>18</sup> (β)	(976)
MnBr <sub>2</sub> .....	c	380	67 (analogy)	
MnBr <sub>2</sub> .....	aq.	447	ions	
MnBr <sub>2</sub> (?).....	aq.	456	Mn + Br	(359)
MnI <sub>2</sub> .....	aq.	320	ions	
MnS.....	ppt.	198	MnSO <sub>4</sub> + Na <sub>2</sub> S; &	(50, 976)
	c	250 (7)	Mn + S	(1019)
MnSO <sub>4</sub> .....	c	1034	57.7 <sup>18</sup> (β)	(458, 976)
	400	1092.8	H <sub>2</sub> SO <sub>4</sub> + MnCl <sub>2</sub> ; &	(976)
	200	1002.6	dil.	
	100	1091.9	dil.	
	50	1091.2	dil.	
	20	1090.1	dil.	
MnSO <sub>4</sub> .H <sub>2</sub> O.....	c	1345	32.6 <sup>18</sup> (β)	(976)
MnSO <sub>4</sub> .5H <sub>2</sub> O.....	c	2523	0.2 <sup>18</sup> (β)	(219, 458, 976)
MnSO <sub>4</sub> .7H <sub>2</sub> O.....	c	3117	dissoc.*	(219)
MnS <sub>2</sub> O <sub>8</sub> .....	400	1355	ions	
MnS <sub>2</sub> O <sub>8</sub> .6H <sub>2</sub> O.....	c	3081	-8.1 <sup>18</sup> (β)	(976)
MnSe.....	ppt.	114 (7)	MnSO <sub>4</sub> + Na <sub>2</sub> Se	(359)
	c	100	+ Br <sub>2</sub>	(359)
MnN <sub>2</sub> .....	c	-386	dissoc.	(1113)
Mn(NO <sub>3</sub> ) <sub>2</sub> .....	c	570	53.1 <sup>14</sup> (β)	(482)
	400	624	Ba(NO <sub>3</sub> ) <sub>2</sub> + MnSO <sub>4</sub>	analogy
	6	615.6	→ c	(1105)
	3	613	analogy	(1105)
Mn(NO <sub>3</sub> ) <sub>2</sub> .3H <sub>2</sub> O.....	c	1499	→ liq.	(732)
Mn(NO <sub>3</sub> ) <sub>2</sub> .6H <sub>2</sub> O.....	c	2367	-25.7 <sup>18</sup> (β)	(976)
MnCl <sub>2</sub> .NH <sub>3</sub> .....	c	608	dissoc.*	(199*)
MnCl <sub>2</sub> .2NH <sub>3</sub> .....	c	733	dissoc.*	(199*)
MnCl <sub>2</sub> .2NH <sub>3</sub> .Cl.2H <sub>2</sub> O.....	c	1730	-23.8	(371)
MnCl <sub>2</sub> .6NH <sub>3</sub> .....	c	1125	dissoc.*	(199, 332*)
MnBr <sub>2</sub> .NH <sub>3</sub> .....	c	518	dissoc.*	(199*)
MnBr <sub>2</sub> .2NH <sub>3</sub> .....	c	649	dissoc.*	(199*)
MnBr <sub>2</sub> .2NH <sub>3</sub> .Br.....	400	700	mix.	(1013)
MnBr <sub>2</sub> .6NH <sub>3</sub> .....	c	1072	dissoc.*	(199, 334*)
MnSO <sub>4</sub> .(NH <sub>4</sub> ) <sub>2</sub> SO <sub>4</sub> .6H <sub>2</sub> O.....	c	4002	-41	(488)
Mn <sub>2</sub> (PO <sub>4</sub> ) <sub>3</sub> .....	coll.	3081	MnCl <sub>2</sub> + Na <sub>2</sub> HPO <sub>4</sub>	(129)
	c	3068	MnCl <sub>2</sub> + Na <sub>2</sub> HPO <sub>4</sub> ; &	(129, 868, 889)
	c	52	+ O <sub>2</sub>	(619, 893, 997)
Mn <sub>2</sub> C.....	c	891	+ O <sub>2</sub>	(619, 1018)
MnCO <sub>3</sub> .....	c	872	MnCl <sub>2</sub> + K <sub>2</sub> CO <sub>3</sub> ; &	(58, 976)
	ppt.	1086	MnCl <sub>2</sub> + K <sub>2</sub> C <sub>2</sub> O <sub>4</sub>	(58)
MnCrO <sub>4</sub> .....	ppt.	1014	18 <sup>24</sup> (β)	(58)
Mn(CHO <sub>2</sub> ) <sub>2</sub> .....	c	1033	+ KOH	(58)
Mn(CHO <sub>2</sub> ) <sub>2</sub> .2H <sub>2</sub> O.....	c	1617	-12 <sup>24</sup> (β)	(58)
Mn(C <sub>2</sub> H <sub>3</sub> O <sub>2</sub> ) <sub>2</sub> .....	c	1142	51 <sup>17</sup> (β)	(976)
	aq.	1194	N	(58)
Mn(C <sub>2</sub> H <sub>3</sub> O <sub>2</sub> ) <sub>2</sub> .4H <sub>2</sub> O.....	c	2331	7 <sup>16</sup> (β)	(976)
MnSiO <sub>3</sub> .....	c	1253	222.1 (m% HF)	(740)
	gls.	1217	MnCO <sub>3</sub> + SiO <sub>2</sub>	(619, 740, 1019)
MnBr <sub>2</sub> .2HgBr <sub>2</sub> .....	8400	773	mix.	(1012)
MnBr <sub>2</sub> .HgBr <sub>2</sub> .....	4400	616	mix.	(1012)
2MnBr <sub>2</sub> .HgBr <sub>2</sub> .....	4400	1075	mix.	(1012)

<b>Iron*</b>				
Fe(α).....	c	0	Def.	
Fe(β).....	c		Tr.; 1.3 <sup>728</sup> (α)	(611, 774, 926, 1071)
Fe(γ).....	c		Tr.; 1.4 <sup>816</sup> (β)	(616, 611, 774, 818)

\* Fe<sub>2</sub>O<sub>3</sub>; heat of hydration (717). Reciprocal heat of mixing of Fe<sub>2</sub>(SO<sub>4</sub>)<sub>3</sub> solutions with Cu(NO<sub>3</sub>)<sub>2</sub>; Zn(Ac)<sub>2</sub>; Zn(NO<sub>3</sub>)<sub>2</sub>; MnCl<sub>2</sub>; Mn(Ac)<sub>2</sub>; FeSO<sub>4</sub>; MnSO<sub>4</sub> (51, 69). Heat of dissociation of amines of FeBr<sub>2</sub> and FeI<sub>2</sub>; Fe<sub>2</sub>(SO<sub>4</sub>)<sub>3</sub>.12NH<sub>3</sub>; FeBr<sub>2</sub>.6NH<sub>3</sub>; FeCl<sub>2</sub>.6NH<sub>3</sub>; FeSO<sub>4</sub>.6NH<sub>3</sub>; K<sub>2</sub>FeCl<sub>6</sub>.6NH<sub>3</sub>; heat of dissociation (332, 343).



Formula	State	Q, kj	Method	Lit.	Formula	State	Q, kj	Method	Lit.
<b>Iron.—(Continued)</b>					<b>Iron.—(Continued)</b>				
Fe( $\delta$ )	c		Tr.; 0.42 <sup>1400</sup> <sub>(7)</sub>	(697, 818, 819, 1069)	Fe(NO <sub>3</sub> ) <sub>3</sub> ·9H <sub>2</sub> O	c	3276	-38 <sub>100</sub>	(55)
Fe <sup>++</sup>	aq.	87	FeCl <sub>2</sub>		FeNOCl <sub>2</sub>	aq.	372	FeCl <sub>2</sub> + NO; &	(437, 661)
Fe <sup>+++</sup>	aq.	40	FeCl <sub>3</sub>		FeCl <sub>2</sub> ·NH <sub>3</sub>	c	483	dissoc.*	(199)
FeO	c	268	+H <sub>2</sub> ; &	(327, * 618, 715, 893, * 912, * 977, 993*)	FeCl <sub>2</sub> ·2NH <sub>3</sub>	c	614	dissoc.*	(199)
Fe <sub>2</sub> O <sub>3</sub> (calcined)	amorp.	802	+Na <sub>2</sub> O <sub>2</sub>	(618, 619, 715, 912, * 993*)	FeCl <sub>2</sub> ·6NH <sub>3</sub>	c	1027	dissoc.*	(323)
Fe <sub>2</sub> O <sub>3</sub> (ordinary)	c	798	Tr.; 4 <sup>18</sup> <sub>(calcined)</sub>	(618)	FeNOSO <sub>4</sub>	aq.	923	FeSO <sub>4</sub> + NO	(437, 661)
Fe <sub>2</sub> O <sub>4</sub> (fused)	c	1113	Fe + O; &	(34.5, 308, 327, * 715, 892)	FeSO <sub>4</sub> ·(NH <sub>4</sub> ) <sub>2</sub> SO <sub>4</sub> ·6H <sub>2</sub> O	c	3881	-41	(458)
Fe <sub>2</sub> O <sub>4</sub> (I)	c		Tr.; 0.4 <sup>750</sup> <sub>(II)</sub>	(609, 1041)	Fe <sub>2</sub> (SO <sub>4</sub> ) <sub>3</sub> ·(NH <sub>4</sub> ) <sub>2</sub> SO <sub>4</sub>	1000	1919	mix.	(51)
Fe <sub>2</sub> O <sub>4</sub> (II)	c		Tr.; 2.4 <sup>485</sup> <sub>(III)</sub>	(609)	NH <sub>4</sub> Fe(SO <sub>4</sub> ) <sub>2</sub> ·12H <sub>2</sub> O	c	5423	-69	(46.1)
Fe <sub>2</sub> O <sub>4</sub> (III) (magnetite)	c	1117	+Na <sub>2</sub> O <sub>2</sub>	(715)	Fe <sub>3</sub> C	c	-19.25	+CO <sub>2</sub> ; &	(691, * 892, * 908, * 997)
Fe(OH) <sub>2</sub>	ppt.	568.6	FeCl <sub>2</sub> + NaOH	(976)	FeCO <sub>3</sub>	ppt.	750	Na <sub>2</sub> CO <sub>3</sub> + FeSO <sub>4</sub>	(58)
Fe(OH) <sub>3</sub>	ppt.	826	FeCl <sub>3</sub> + NaOH	(793)		c	775	dissoc.*	(618*)
FeF <sub>2</sub>	1200	741	FeCl <sub>2</sub> + AgF	(793)	Fe <sub>2</sub> (C <sub>2</sub> O <sub>4</sub> ) <sub>3</sub>	100	2553	+KOH; &	(624)
FeF <sub>3</sub>	150	1015	FeCl <sub>3</sub> + AgF; &	(740, 793)		400	2552	+KOH; &	(624)
	1200	1018	FeCl <sub>3</sub> + AgF	(793)	Fe(C <sub>2</sub> H <sub>2</sub> O <sub>2</sub> ) <sub>3</sub>	1800	1495	Ba(C <sub>2</sub> H <sub>2</sub> O <sub>2</sub> ) <sub>2</sub> + Fe <sub>2</sub> (SO <sub>4</sub> ) <sub>3</sub>	(51, 976)
FeCl <sub>2</sub>	c	342.6	74.9 <sup>18</sup> <sub>400</sub>	(976)		600	1500	dil.	(51)
FeCl <sub>2</sub> ·2H <sub>2</sub> O	c	400	Fe + HCl	(869, 976)	Fe(CN) <sub>6</sub> <sup>4-</sup>	300	1501	dil.; &	(70)
FeCl <sub>2</sub> ·4H <sub>2</sub> O	c	953	36 <sup>20</sup> <sub>300</sub>	(898)	Fe(CN) <sub>6</sub> <sup>3-</sup>	aq.	-613	K <sub>2</sub> Fe(CN) <sub>6</sub>	
FeCl <sub>3</sub>	c	1550	11.5 <sup>18</sup> <sub>400</sub>	(898)	Fe <sub>4</sub> (Fe(CN) <sub>6</sub> ) <sub>3</sub>	aq.	-510	K <sub>4</sub> Fe(CN) <sub>6</sub>	
	c	403	133	(624)		ppt.	-1335	K <sub>2</sub> Fe(CN) <sub>6</sub> + FeSO <sub>4</sub> ; &	(70)
	1000	536	FeCl <sub>2</sub> + HClO; &	(898, 976)	FeCO(CN) <sub>5</sub>	aq.	-181	K <sub>2</sub> FeCO(CN) <sub>5</sub>	
	200	532	dil.	(624)	Fe <sub>2</sub> CO(CN) <sub>4</sub>	c	-393	+O <sub>2</sub>	(744)
	100	528	dil.		HFe(CN) <sub>5</sub>	aq.	-614	K <sub>2</sub> HFe(CN) <sub>5</sub>	
	50	515	dil.		HFe(CN) <sub>4</sub>	aq.	-510	K <sub>2</sub> HFe(CN) <sub>4</sub>	
	20	430	dil.	(793)	H <sub>2</sub> Fe(CN) <sub>4</sub>	aq.	-617	KH <sub>2</sub> Fe(CN) <sub>4</sub>	
FeCl <sub>3</sub> ·2.5H <sub>2</sub> O	c	1163	88 <sup>18</sup> <sub>1200</sub>	(898, 900)	H <sub>2</sub> Fe(CN) <sub>3</sub>	aq.	-511	K <sub>2</sub> H <sub>2</sub> Fe(CN) <sub>3</sub>	
FeCl <sub>3</sub> ·6H <sub>2</sub> O	c	2229	24 <sup>21</sup> <sub>1200</sub>	(898, 900)	H <sub>2</sub> Fe(CN) <sub>2</sub>	aq.	-620	N	(558)
Fe(ClO <sub>3</sub> ) <sub>3</sub>	600	282	Ba(ClO <sub>3</sub> ) <sub>2</sub> + Fe <sub>2</sub> (SO <sub>4</sub> ) <sub>3</sub>	(976)	H <sub>2</sub> Fe(CN) <sub>1</sub>	aq.	-511	KH <sub>2</sub> Fe(CN) <sub>1</sub>	
FeCl <sub>3</sub> ·2HCl	500	864.4	FeCl <sub>2</sub> + HClO; & ions	(793, 976)	H <sub>2</sub> Fe(CN) <sub>0</sub>	c	-514	1.7 <sup>10</sup> <sub>200</sub> ; &	(277)
FeBr <sub>2</sub>	aq.	326	ions; &	(380)	(NH <sub>4</sub> ) <sub>4</sub> Fe(CN) <sub>6</sub>	aq.	18	N	(558)
FeBr <sub>3</sub>	1000	398	ions; &		(NH <sub>4</sub> ) <sub>4</sub> Fe(CN) <sub>6</sub> ·3H <sub>2</sub> O	c	904	-28 <sup>14</sup>	(558)
FeI <sub>2</sub>	aq.	199	ions		H <sub>2</sub> FeCO(CN) <sub>3</sub>	aq.	-181	22 <sup>19</sup> <sub>3600</sub>	(744)
FeI <sub>3</sub>	1000	207	ions		H <sub>2</sub> FeCO(CN) <sub>2</sub> ·H <sub>2</sub> O	c	83	+O <sub>2</sub>	(744)
FeS	c	96.5	Fe + S; &	(853, * 662, 779)	H <sub>2</sub> Fe(CN) <sub>1</sub> ·(C <sub>2</sub> H <sub>5</sub> ) <sub>2</sub> O	c		255 <sup>12</sup> <sub>KOH</sub>	(277)
	ppt.	98	FeSO <sub>4</sub> + Na <sub>2</sub> S	(80, 976)	Fe <sub>3</sub> Si	c	-80	+O <sub>2</sub> ; &	(258, 289, 776, 997)
FeS(natural)	c	80	+Na <sub>2</sub> O <sub>2</sub>	(715)	FeSiO <sub>3</sub>	c	1107	FeCO <sub>3</sub> + SiO <sub>2</sub> ; &	(618, 619, 1018)
FeS <sub>2</sub> (pyrite)	c	149	Na <sub>2</sub> O <sub>2</sub> ; &	(877, * 715)	ZnFe(CN) <sub>6</sub>	c	-167	K <sub>4</sub> Fe(CN) <sub>6</sub> + ZnSO <sub>4</sub>	(558)
FeS <sub>2</sub> (marcasite)	c	149	+Na <sub>2</sub> O <sub>2</sub>	(715)					
FeSO <sub>4</sub>	c	909.1	62.36 <sup>14</sup> <sub>110</sub>	(417, 976)					
	400	970.7	+HCl	(976)	Co(II)	c	0	Def.	
	200	970.5	+HCl; &	(976)	Co(I)	c		Tr.; 0.33 <sup>1000</sup> <sub>(II)</sub>	(618, 1069)
FeSO <sub>4</sub> ·H <sub>2</sub> O	c	1226.1	31.5 <sup>14</sup> <sub>300</sub>	(417)	Co <sup>++</sup>	aq.	69	CoCl <sub>2</sub>	
FeSO <sub>4</sub> ·4H <sub>2</sub> O	c	2109.4	6.7 <sup>14</sup> <sub>300</sub>	(417)	CoO	c	241	+O <sub>2</sub>	(322, 372, 712)
FeSO <sub>4</sub> ·7H <sub>2</sub> O	c	2992.7	-18.1 <sup>14</sup> <sub>300</sub>	(389, 417, 488, 976)	Co <sub>2</sub> O <sub>3</sub>	amorp.	210	+Na <sub>2</sub> O <sub>2</sub>	(712)
Fe <sub>2</sub> (SO <sub>4</sub> ) <sub>3</sub>	1200	2685.8	Fe <sub>2</sub> (SO <sub>4</sub> ) <sub>3</sub> + BaCl <sub>2</sub> ; &	(69, 823, * 961, 976)	Co(OH) <sub>2</sub>	c	806	+Na <sub>2</sub> O <sub>2</sub>	(712)
	400	2685	dil.	(51, 624, 976)	Co(OH) <sub>3</sub>	ppt.	537	CoSO <sub>4</sub> + NaOH; &	(976)
	300	2684	dil.			ppt.	918	Co(OH) <sub>2</sub> + NaOCl; &	(976)
	150	2682	dil.		CoF <sub>2</sub>	aq.	723.2	CoCl <sub>2</sub> + AgF	(793)
	50	2661	dil.		CoCl <sub>2</sub>	c	322.0	77.2 <sup>17</sup> <sub>400</sub>	(976)
Fe <sub>2</sub> (SO <sub>4</sub> ) <sub>3</sub> ·3H <sub>2</sub> SO <sub>4</sub>	1200	5302	Fe <sub>2</sub> (SO <sub>4</sub> ) <sub>3</sub> + H <sub>2</sub> SO <sub>4</sub>	(69)	CoCl <sub>2</sub> ·2H <sub>2</sub> O	400	399.2	Co + HCl	(181, 976)
FeSe	c	80	+Br	(260)	CoCl <sub>2</sub> ·6H <sub>2</sub> O	c	930.3	41.2 <sup>23</sup> <sub>400</sub>	(900)
	ppt.	60	FeSO <sub>4</sub> + Na <sub>2</sub> S	(280)	CoBr <sub>2</sub>	c	2128.2	-11.9 <sup>13</sup> <sub>400</sub>	(976)
FeTe	c	32	+Br	(281)	CoBr <sub>2</sub> ·6H <sub>2</sub> O	c	230	77; &	(301)
FeNO <sup>-</sup>	aq.	40	FeNOSO <sub>4</sub>		CoI <sub>2</sub>	aq.	307	Co + Br <sub>2</sub>	(301, 380)
Fe(NO <sub>2</sub> ) <sub>2</sub>	aq.	503	ions		CoS	c	2030	-5.4	(301)
Fe(NO <sub>2</sub> ) <sub>3</sub>	800	663	N	(55)	Co <sub>2</sub> S <sub>3</sub>	aq.	179	ions; &	(518)
	200	667	dil.		CoSO <sub>4</sub>	ppt.	83	Na <sub>2</sub> S + CoSO <sub>4</sub>	(553, 976)
						ppt.	167 (?)	analogy	
						800	942.0	+HCl	(976)
						200	941.6	+HCl	(976)

\* CoI<sub>2</sub> amines, heat of dissociation (183, 190). CoCl<sub>2</sub>·(NH<sub>3</sub>)<sub>6</sub>, heat of dissociation (190). CoSO<sub>4</sub> amines, heat of dissociation (330). CoSO<sub>4</sub>·(NH<sub>4</sub>)<sub>2</sub>SO<sub>4</sub>·6H<sub>2</sub>O, heat of dissociation (362).



Formula	State	Q, kj	Method	Lit.
<b>Cobalt.—(Continued)</b>				
CoSO <sub>4</sub> ·7H <sub>2</sub> O	c	2960	-14.9 <sup>19</sup> <sub>800</sub>	(976)
CoSe	c	56	+Br <sub>2</sub>	(356)
	ppt.	48	Na <sub>2</sub> Se + CoSO <sub>4</sub>	(356)
CoTe	c	48	+Br <sub>2</sub>	(351)
Co(NO <sub>3</sub> ) <sub>2</sub>	c	436	50 <sup>18</sup> <sub>300</sub>	(482)
	3	470	→c	(1198)
Co(NO <sub>3</sub> ) <sub>2</sub> ·6H <sub>2</sub> O	aq.	486	ions	
[Co.5NH <sub>3</sub> .H <sub>2</sub> O] <sup>++</sup>	c	2223	-20.8 <sup>18</sup> <sub>400</sub>	(976)
	aq.	747	[Co.5NH <sub>3</sub> .-H <sub>2</sub> O](NO <sub>3</sub> ) <sub>2</sub>	
[Co.5NH <sub>3</sub> .NO <sub>3</sub> ] <sup>++</sup>	aq.	667	[Co.5NH <sub>3</sub> .-NO <sub>3</sub> ](NO <sub>3</sub> ) <sub>2</sub>	
[Co.5NH <sub>3</sub> .NO <sub>3</sub> ](NO <sub>3</sub> ) <sub>2</sub>	c	1146	-62.4 <sup>25</sup>	(602)
	aq.	1084	+Na <sub>2</sub> S = Co <sub>2</sub> S <sub>3</sub> + etc.	(602)
[Co.5NH <sub>3</sub> .H <sub>2</sub> O](NO <sub>3</sub> ) <sub>2</sub>	c	1437	-64.4 <sup>25</sup>	(602)
	aq.	1372	+Na <sub>2</sub> S = Co <sub>2</sub> S <sub>3</sub> + etc.	(602)
CoCl <sub>2</sub> ·NH <sub>3</sub>	c	457	dissoc.* & dissoc.*	(183*)
CoCl <sub>2</sub> ·2NH <sub>3</sub> (α rose)	c	581	dissoc.*	(183)
[Co.5NH <sub>3</sub> .Cl] <sup>++</sup>	aq.	613	[Co.5NH <sub>3</sub> .Cl]Cl <sub>2</sub>	
[Co.5NH <sub>3</sub> .Cl]Cl <sub>2</sub>	c	996	-52.0 <sup>25</sup>	(602)
	aq.	943	+Na <sub>2</sub> S = Co <sub>2</sub> S <sub>3</sub> + etc.	(602)
CoCl <sub>2</sub> ·6NH <sub>3</sub>	c	1000	dissoc.*	(183, 190, 332)
[Co.5NH <sub>3</sub> .H <sub>2</sub> O]Cl <sub>2</sub>	c	1265	-27.0 <sup>25</sup>	(602)
	aq.	1238	+Na <sub>2</sub> S = Co <sub>2</sub> S <sub>3</sub> + etc.	(602)
CoBr <sub>2</sub> ·NH <sub>3</sub>	c	367	dissoc.*	(183*)
CoBr <sub>2</sub> ·2NH <sub>3</sub>	c	503	dissoc.*	(183*)
(NH <sub>4</sub> ) <sub>2</sub> CoBr <sub>4</sub>	aq.	904.2	CoBr <sub>2</sub> + NH <sub>4</sub> Br	(1012)
[Co.5NH <sub>3</sub> .Br] <sup>++</sup>	aq.	575	[Co.5NH <sub>3</sub> .-Br]Br <sub>2</sub>	
[Co.5NH <sub>3</sub> .Br]Br <sub>2</sub>	c	867	-53.0 <sup>25</sup>	(602)
	aq.	814	+Na <sub>2</sub> S = Co <sub>2</sub> S <sub>3</sub> + etc.	(602)
CoBr <sub>2</sub> ·6NH <sub>3</sub>	c	963	dissoc.*	(183, 334)
[Co.5NH <sub>3</sub> .H <sub>2</sub> O]Br <sub>2</sub>	c	1145	-38.6 <sup>25</sup>	(602)
	aq.	1107	+Na <sub>2</sub> S = Co <sub>2</sub> S <sub>3</sub> + etc.	(602)
Co(C <sub>2</sub> H <sub>3</sub> SO <sub>4</sub> ) <sub>2</sub>	aq.	1872	CoSO <sub>4</sub> + Ba(C <sub>2</sub> H <sub>3</sub> SO <sub>4</sub> ) <sub>2</sub>	(976)
½CoBr <sub>2</sub> ·HgBr <sub>2</sub>	4200	316	mix.	(1012)
CoBr <sub>2</sub> ·HgBr <sub>2</sub>	4400	475	mix.	(1012)
2CoBr <sub>2</sub> ·HgBr <sub>2</sub>	4800	791	mix.	(1012)
<b>Nickel<sup>a</sup></b>				
Ni(α)	c	0	Def.	
Ni(β)	c		Tr.: 0.3 <sup>355</sup> <sub>(α)</sub>	(610, 611, 818, 1041, 1045, 1069)
Ni <sup>++</sup>	aq.	64	NiCl <sub>2</sub>	
NiO	c	242	Ni + O; * &	(322, 712, 784, 894, 992, 1055*)
Ni(OH) <sub>2</sub>	ppt.	543.2	NiSO <sub>4</sub> + KOH; &	(976)
Ni(OH) <sub>2</sub>	ppt.	823	Ni(OH) <sub>2</sub> + NaOCl	(976)
NiF <sub>2</sub>	aq.	717.8	NiCl <sub>2</sub> + AgF	(740, 793)
NiCl <sub>2</sub>	c	313.8	80.2 <sup>18</sup> <sub>400</sub>	(976)
	800	394.5	dil.	
	400	394.1	Ni + HCl	(976)
	200	393.4	dil.	(976)
	100	392.5	dil.	
	50	391.2	dil.	
	20	386.7	dil.	
NiCl <sub>2</sub> ·2H <sub>2</sub> O	c	92.3	43 <sup>19</sup> <sub>400</sub>	(900)
NiCl <sub>2</sub> ·6H <sub>2</sub> O	c	2115.7	-4.8 <sup>19</sup> <sub>400</sub>	(976)
NiBr <sub>2</sub>	c	223	79; &	(301)
	aq.	303	ions; &	(301, 350)
NiBr <sub>2</sub> ·3H <sub>2</sub> O	c	1160	1.0	(301)

\* For other amines (190, 332, 341). NiSO<sub>4</sub>(NH<sub>4</sub>)<sub>2</sub>SO<sub>4</sub>·6H<sub>2</sub>O, heat of dissociation (362).

Formula	State	Q, kj	Method	Lit.
<b>Nickel.—(Continued)</b>				
NiH <sub>2</sub>	aq.	175	ions	
NiS	ppt.	87	NiSO <sub>4</sub> + Na <sub>2</sub> S	(976)
NiSO <sub>4</sub>	400	950.2	NiCl <sub>2</sub> + H <sub>2</sub> SO <sub>4</sub>	(976)
NiSO <sub>4</sub> ·7H <sub>2</sub> O	c	2971.8	-17.8 <sup>19</sup> <sub>800</sub>	(976)
Ni <sub>2</sub> O <sub>3</sub>	aq.	1214	ions	
Ni <sub>2</sub> O <sub>3</sub> ·6H <sub>2</sub> O	c	2941	-10.1 <sup>19</sup> <sub>400</sub>	(976)
NiSe	c	56	+Br	(356)
	ppt.	62	NiSO <sub>4</sub> + Na <sub>2</sub> Se	(356)
NiTe	c	45	+Br	(356)
NiN <sub>4</sub> ·H <sub>2</sub> O	c	-133	dissoc.	(1113)
Ni(NO <sub>3</sub> ) <sub>2</sub>	c	430	49 <sup>18</sup> <sub>280</sub>	(482)
	400	479	ions	
Ni(NO <sub>3</sub> ) <sub>2</sub> ·6H <sub>2</sub> O	c	2227.5	-31.3 <sup>18</sup> <sub>400</sub>	(976)
NiCl <sub>2</sub> ·NH <sub>3</sub>	c	450	74HCl; &	(182)
NiCl <sub>2</sub> ·2NH <sub>3</sub>	c	575	82HCl; &	(182, 332†)
NiCl <sub>2</sub> ·6NH <sub>3</sub>	c	1041	185HCl; &	(182, 332†)
NiBr <sub>2</sub> ·NH <sub>3</sub>	c	356	dissoc.*	(190†)
NiBr <sub>2</sub> ·2NH <sub>3</sub>	c	488	dissoc.*	(190†)
NiBr <sub>2</sub> ·6NH <sub>3</sub>	c	928	dissoc.*	(190, 332†)
Ni <sub>2</sub> C	c	-166	+O <sub>2</sub>	(894)
Ni(CN) <sub>2</sub>	c	-97.3	NiSO <sub>4</sub> + KCN; &	(1010, 1011)
Ni(CN) <sub>4</sub> <sup>2-</sup>	aq.	-338.4	K <sub>2</sub> Ni(CN) <sub>4</sub>	
NiBr <sub>2</sub> ·2HgBr <sub>2</sub>	4200	628	mix.	(1012)
2NiBr <sub>2</sub> ·HgBr <sub>2</sub>	4400	470	mix.	(1012)
<b>Tungsten<sup>a</sup></b>				
W	c	0	Def.	
W(wire)	c	0	W + O <sub>2</sub>	(848)
WO <sub>2</sub>	c	528	WO <sub>2</sub> + H <sub>2</sub> * &	(307, 648)
WO <sub>3</sub>	c	801	W + O <sub>2</sub> ; &	(307, 648, 767, 730.5, 1039)
W <sub>2</sub> O <sub>5</sub>	c	1302	+H <sub>2</sub> O	(648)
H <sub>2</sub> WO <sub>4</sub>	c	1172	dissoc.*	(830*)
	aq.	1172	Na <sub>2</sub> WO <sub>4</sub> + H <sub>2</sub> SO <sub>4</sub>	(830)
WO <sub>2</sub> ·H <sub>2</sub> O <sub>2</sub>	aq.	1363	H <sub>2</sub> WO <sub>4</sub> + H <sub>2</sub> O <sub>2</sub>	(826)
WO <sub>2</sub> ·2H <sub>2</sub> O <sub>2</sub>	aq.	1514	H <sub>2</sub> WO <sub>4</sub> + H <sub>2</sub> O <sub>2</sub>	(826)
WO <sub>2</sub> ·3H <sub>2</sub> O <sub>2</sub>	aq.	2126	H <sub>2</sub> WO <sub>4</sub> + H <sub>2</sub> O <sub>2</sub>	(826)
<b>Uranium</b>				
U	c	0	Def.	
UO <sub>2</sub>	c	1074	+Na <sub>2</sub> O <sub>2</sub>	(714)
UO <sub>2</sub> <sup>++</sup>	aq.	1010	UO <sub>2</sub> Cl <sub>2</sub>	
UO <sub>3</sub>	c	1214	+Na <sub>2</sub> O <sub>2</sub>	(714)
U <sub>2</sub> O <sub>5</sub>	c	3537	+Na <sub>2</sub> O <sub>2</sub> ; &	(714)
UO <sub>2</sub> ·½H <sub>2</sub> O	c	1357	dissoc.*	(830*)
UO <sub>2</sub> ·H <sub>2</sub> O	c	1520	62.1HNO <sub>3</sub> (100)	(421, 830)
UO <sub>2</sub> ·1½H <sub>2</sub> O	c	1672	dissoc.*	(830*)
UO <sub>2</sub> ·2H <sub>2</sub> O	c	1820	51.8HNO <sub>3</sub> (100)	(7, 421, 830)
UO <sub>2</sub> ·2H <sub>2</sub> O	c	1841	H <sub>2</sub> O <sub>2</sub> + UO <sub>2</sub> SO <sub>4</sub>	(826)
UO <sub>2</sub> Cl <sub>2</sub>	aq.	1340	UO <sub>2</sub> ·2H <sub>2</sub> O + HCl; &	(7)
UO <sub>2</sub> Cl <sub>2</sub> ·H <sub>2</sub> O	c	1600	25 <sup>18</sup> <sub>1000</sub>	(7)
UO <sub>2</sub> SO <sub>4</sub>	aq.	1881	UO <sub>2</sub> ·2H <sub>2</sub> O + H <sub>2</sub> SO <sub>4</sub> ; &	(7, 830)
UO <sub>2</sub> SO <sub>4</sub> ·3H <sub>2</sub> O	c	2720	21 <sup>18</sup> <sub>1000</sub>	(7)
UO <sub>2</sub> (NO <sub>3</sub> ) <sub>2</sub>	c	1348	79 <sup>12</sup> <sub>220</sub>	(421, 867)
	aq.	1427	UO <sub>2</sub> + HNO <sub>3</sub> ; &	(421)
UO <sub>2</sub> (NO <sub>3</sub> ) <sub>2</sub> ·H <sub>2</sub> O	c	1663	49.7 <sup>12</sup> <sub>220</sub>	(421)
UO <sub>2</sub> (NO <sub>3</sub> ) <sub>2</sub> ·2H <sub>2</sub> O	c	1979	21.1 <sup>12</sup> <sub>220</sub>	(421, 867)
UO <sub>2</sub> (NO <sub>3</sub> ) <sub>2</sub> ·3H <sub>2</sub> O	c	2278	7.7 <sup>12</sup> <sub>220</sub>	(7, 296, 421, 867)
UO <sub>2</sub> (NO <sub>3</sub> ) <sub>2</sub> ·6H <sub>2</sub> O	c	3167	-22.8 <sup>12</sup> <sub>220</sub>	(421)
UC <sub>2</sub>	c	121	UO <sub>2</sub> + C	(814)
UO <sub>2</sub> (C <sub>2</sub> H <sub>3</sub> O <sub>2</sub> ) <sub>2</sub>	aq.	1994	ions	

\* Hg + Cl<sup>-</sup> + W(CN)<sub>8</sub><sup>4-</sup> = HgCl + W(CN)<sub>8</sub><sup>4-</sup>; ΔQ = 70.5 (1085\*).



Formula	State	Q, kJ	Method	Lit.
<b>Uranium.—(Continued)</b>				
$\text{UO}_2(\text{C}_2\text{H}_3\text{O}_2)_2 \cdot 2\text{H}_2\text{O}$ .....	c	2585	$-18_{1000}^{18}$	(7)
$\text{UO}_2(\text{C}_2\text{H}_3\text{O}_2)_2 \cdot \text{NH}_4\text{C}_2\text{H}_3\text{O}_2 \cdot 6\text{H}_2\text{O}$ .....	c	4353	$-16_{1000}^{18}$	(7)
$\text{UO}_2\text{CrO}_4$ .....	aq.	1862	ions	
$\text{UO}_2\text{CrO}_4 \cdot 5\text{H}_2\text{O}$ .....	c	3463	$-28_{1000}^{18}$	(7)
<b>Vanadium<sup>a</sup></b>				
V.....	c	0	Def.	
$\text{VO}_2^-$ .....	aq.	1066	$\text{KVO}_2$	
$\text{VO}_4^{3-}$ .....	aq.	1006	$\text{KVO}_4$	
$\text{VO}_5^{3-}$ .....	aq.	944	$\text{KVO}_5$	
$\text{V}_2\text{O}_5$ .....	c	875	$+\text{Na}_2\text{O}_2$	(714, 891, 895)
$\text{V}_2\text{O}_5$ .....	c	1463	$+\text{Na}_2\text{O}_2$	(714, 891)
$\text{V}_2\text{O}_4$ .....	c	1712	$+\text{Na}_2\text{O}_2$	(714)
$\text{V}_2\text{O}_5$ .....	c	1830	$+\text{Na}_2\text{O}_2$ ; &	(714, 891)
$\text{VCl}_3$ .....	c	616	$+\text{O}_2$	(891)
$\text{VCl}_3$ .....	liq.	783	$+\text{O}_2$	(891)
$\text{VCl}_4$ .....	liq.	678	$+\text{NaHO}_2$	(891)
$\text{VOCl}_3$ .....	liq.	842	$+\text{NaHO}_2$	(891)
<b>Tantalum</b>				
Ta.....	c	0	Def.	
$\text{Ta}_2\text{O}_5$ .....	c	1256	$\text{Ta} + \text{O}_2$	(730.5)
<b>Chromium<sup>b</sup></b>				
$\text{Cr}_\alpha$ .....	c	0	Def.	
$\text{Cr}_\beta$ .....	c		Tr.; $0.54_{\alpha}^{486}$	(611)
$[\text{Cr}]_{(\text{blue})}^{+++} = (\text{Cr} \cdot 6\text{H}_2\text{O})^{+++}$ .....	aq.	256	$[\text{Cr}]\text{Cl}_3$	
$\text{CrO}_3$ .....	c	569	$10.3_{80}^{18}$	(280, 733, 899)
$\text{CrO}_3(\text{fumed})$ .....	c	583	$+\text{Na}_2\text{O}_2$	(707, 716)
$\text{CrO}_3$ .....	80.0	579.2	N, $\text{Na}_2\text{CrO}_4$	(120, 899, 976)
	49.9	579.0	dil.	(280, 733)
	25.2	578.6	dil.	
	10.1	577	dil.	
	4.03	574.4	dil.	
	3.32	573.0	dil.	
$\text{CrO}_4^{2-}$ .....	aq.	853	$\text{Na}_2\text{CrO}_4$	
$\text{Cr}_2\text{O}_7^{2-}$ .....	c	1119	$+\text{Na}_2\text{O}_2$	(707, 716)
	amorp.	1114	$+\text{Na}_2\text{O}_2$	(707, 716)
	hydrated	1200	$+\text{Na}_2\text{O}_2$	(707, 716)
$\text{Cr}_2\text{O}_7^{2-}$ .....	aq.	1438	$\text{K}_2\text{Cr}_2\text{O}_7$	
$\text{Cr}_2\text{O}_{10}^{4-}$ .....	aq.	2023	$\text{K}_2\text{Cr}_2\text{O}_{10}$	
$\text{H}_2\text{CrO}_4$ .....	aq.	865	$= \text{CrO}_3$ aq.	
$[\text{Cr}](\text{OH})_3$ .....	ppt.	1029	$[\text{CrCl}_3]\text{Cl} + \text{NaOH}$	(842)
$[\text{CrOH}](\text{OH})_2$ from $[\text{CrOH}]\text{Cl}_2$	ppt.	1011	$+\text{HCl} =$	(842)
$[\text{Cr}(\text{OH})_2]\text{OH}$ .....	ppt.		$[\text{Cr}]\text{Cl}_3 + \text{HCl}; \Delta Q = 42$	(842)
$[\text{Cr}]\text{F}_3(\text{violet})$ .....	aq.	1227.0	$+\text{NaOH}$	(792)
$\text{H}_2[\text{Cr}]\text{F}_6$ .....	aq.	2177	$\text{HF} + [\text{Cr}]\text{F}_3$	(792)
$\text{CrCl}_2$ .....	c	417	78	(842)
	aq.	495	$+\text{O}_2 =$	(842)
$[\text{Cr}]\text{Cl}_3(\text{violet})$ .....	aq.	752	$[\text{CrOH}]\text{Cl}_2$	(842)
$[\text{CrCl}_2]\text{Cl}(\text{green})$ .....	aq.	712	$[\text{Cr}](\text{OH})_3 + \text{HCl}$	(122, 976)
			$\text{K}_2\text{Cr}_2\text{O}_7 + \text{HCl} + \text{KI};$	
			&	
$\text{CrCl}_2 \cdot 4\text{H}_2\text{O}$ .....	c	1631	8	(842)
$\text{CrCl}_2(\text{rose})$ (forms a green solution).....	c	584	128	(842)
$\text{CrCl}_2 \cdot 6\text{H}_2\text{O}(\text{green}) = (\text{CrCl}_2 \cdot 4\text{H}_2\text{O})\text{Cl} \cdot 2\text{H}_2\text{O}$ .....	c	2429	$-0.2_{100}^{18}(\text{to green})$	(841)

<sup>a</sup>  $\text{NaOH} + \text{V}_2\text{F}_6$  (792).  $\text{V}_2\text{O}_5 \cdot \text{H}_2\text{O} + \text{H}_2\text{SO}_4$  (431).

<sup>b</sup>  $(\text{Cr}(\text{NH}_3)_6\text{NO}_3)_2\text{Br}_2$ ;  $(\text{Cr}(\text{NH}_3)_6\text{NO}_3)_2\text{SO}_4$ ;  $\text{CrCl}_2 \cdot 6\text{NH}_3$ ;  $\text{CrCl}_2 \cdot 3\text{NH}_3$ ; heat of dissociation (842). Chromium probably has the coordination number of 6 in all chromic compounds listed. Where the coordination number is not filled out (shown by square brackets) the missing part is water molecules. In calculating heats of formation, the molecular weight taken has been that shown (i.e., Q does not include heat of formation of water molecules not shown).

Formula	State	Q, kJ	Method	Lit.
<b>Chromium.—(Continued)</b>				
$\text{CrCl}_2 \cdot 6\text{H}_2\text{O}(\text{gray}) = (\text{Cr} \cdot 6\text{H}_2\text{O})\text{Cl}_2$ .....	c	2416	50.3 (to blue)	(841)
$\text{CrCl}_2 \cdot 10\text{H}_2\text{O} = (\text{Cr} \cdot 4\text{H}_2\text{O} \cdot \text{Cl})\text{Cl}_2 \cdot 6\text{H}_2\text{O}$ .....	c	3574	0	(518)
$(\text{Cr} \cdot 4\text{H}_2\text{O} \cdot \text{Cl})\text{Cl}_2$ .....	c	1822	35	(518)
$\text{CrO}_2\text{Cl}_2$ .....	gas	513.5	liq.	(37)
	liq.	549	$+\text{H}_2\text{O}$	(87, 88, 110, 724)
$[\text{Cr}]\text{Cl}(\text{OH})_2(\text{violet})$ .....	aq.	921	$+\text{HCl}^*$	(199*)
$[\text{Cr}]\text{Cl}_2\text{OH}(\text{violet})$ .....	aq.	834	$+\text{HCl}^*$	(199*)
$[\text{CrOH}]\text{Cl}_2$ (from $\text{CrCl}_2 + \text{O}_2$ ).....	aq.	746	$+\text{NaOH} =$	(842)
			$[\text{CrOH}](\text{OH})_2$	
$[\text{Cr}]\text{Br}_3(\text{blue})$ .....	aq.	613	$+\text{NaOH}$	(842)
$[\text{CrBr}_2]\text{Br}(\text{green})$ .....	aq.	565	$+\text{NaOH}$	(842)
$(\text{Cr} \cdot 4\text{H}_2\text{O} \cdot \text{Br}_2)\text{Br} \cdot 2\text{H}_2\text{O}(\text{green})$ .....	c	2279	$+2.8_{100}^{18}$	(842)
$(\text{Cr} \cdot 6\text{H}_2\text{O})\text{Br}_2$ .....	c	2270	$-60.0$	(842)
$[\text{Cr}](\text{SO}_4)_2(\text{violet})$ .....	aq.	3155	$[\text{Cr}](\text{OH})_3 + \text{H}_2\text{SO}_4$	(69, 293, 976)
$[\text{Cr}_2\text{SO}_4](\text{SO}_4)_2$ .....	aq.	3135	$+\text{KOH}$	(292)
$[\text{Cr}_2(\text{SO}_4)_2]\text{SO}_4$ .....	aq.	3106	$+\text{KOH}$	(292)
$\text{Cr}_2(\text{SO}_4)_3$ (modified by heat) = $[\text{Cr}_2(\text{SO}_4)_2](\text{OH})_2 + \text{H}_2\text{SO}_4$ (?).....	aq.	3076	$+\text{NaOH};$ &	(843)
$[\text{Cr}_2(\text{SO}_4)_2](\text{green})$ .....	aq.	3059	$+\text{NaOH}$	(843)
$\text{Cr}_2(\text{SO}_4)_3 \cdot 14\text{H}_2\text{O}(\text{violet}) = (\text{Cr} \cdot 6\text{H}_2\text{O})_2(\text{SO}_4)_3 \cdot 2\text{H}_2\text{O}$ .....	c	7119	42.3	(918)
$(\text{Cr} \cdot 6\text{H}_2\text{O})_2(\text{SO}_4)_3 \cdot 3\text{H}_2\text{O}$ .....	c	7412	34.7	(918)
$\text{Cr}_2(\text{SO}_4)_3 \cdot 17\text{H}_2\text{O}(\text{violet}) = (\text{Cr} \cdot 6\text{H}_2\text{O})_2(\text{SO}_4)_3 \cdot 5\text{H}_2\text{O}$ .....	c	7995	26	(843, 918)
$\text{Cr}_2(\text{SO}_4)_3 \cdot 6\text{H}_2\text{O}(\text{green})$ .....	c	4718	56	(843, 918)
$\text{H}_2\text{Cr}_2(\text{SO}_4)_4$ .....	aq.		$+2\text{NaOH};$	(842)
			$\Delta Q = 139$	
$\text{H}_4\text{Cr}_2(\text{SO}_4)_6$ .....	aq.		$+4\text{NaOH};$	(842)
			$\Delta Q = 250$	
$\text{H}_6\text{Cr}(\text{SO}_4)_8$ .....	aq.		$+6\text{NaOH};$	(842)
			$\Delta Q = 400$	
$(\text{NH}_4)_2\text{CrO}_4$ .....	c	1148	$-24_{700}^{18}$	(899)
$(\text{NH}_4)_2\text{Cr}_2\text{O}_7$ .....	aq.	1120	N; &	(119, 723)
	c	1758	$-54_{550}^{18}$	(119, 723, 733)
	600	1705	N	(119, 723, 733)
$\text{CrCl}_2 \cdot 3\text{NH}_3$ .....	c	719.2	dissoc.*	(343*)
$\text{CrCl}_2 \cdot 6\text{NH}_3$ .....	c	996.0	dissoc.*	(343*)
$\text{Cr}_2\text{Cl}_3$ .....	c	544	$\text{Cr}_2\text{O}_3 + \text{C}^*$	(514*)
$\text{PbCrO}_4$ .....	c	913	$\text{Pb}(\text{NO}_3)_2 + \text{K}_2\text{CrO}_4$	(486)

**Molybdenum**

Formula	State	Q, kJ	Method	Lit.
Mo.....	c	0	Def.	
$\text{MoO}_3$ .....	c	556	$\text{Mo} + \text{H}_2\text{O};^*$	(67, 711)
			&	
$\text{MoO}_3$ .....	c	728	$\text{Mo} + \text{O}_2$ ; &	(306, 711, 730.5)
$\text{MoO}_4$ .....	aq.	681	$\text{MoO}_3 + \text{H}_2\text{O};$	(726, 820, 821)
$\text{MoO}_4^{2-}$ .....	aq.	1020	$\text{Na}_2\text{MoO}_4$	(785, 820, 821)
$\text{MoO}_3$ .....	aq.	596	$\text{MoO}_3 + \text{H}_2\text{O};$	(785, 820, 821)
$\text{MoO}_4^{2-}$ .....	aq.	1303	$\text{K}_2\text{MoO}_4$	(785, 820, 821)
$\text{H}_2\text{MoO}_4$ .....	c	1034	dissoc.*	(530*)
	aq.	1032	$\text{H}_2\text{SO}_4 + \text{Na}_2\text{MoO}_4$	(626)
$\text{H}_4\text{MoO}_6$ .....	c	1337	dissoc.	(626)
$24\text{MoO}_3 \cdot 28\text{H}_2\text{O} \cdot 4\text{H}_2\text{O}$ .....	c		$+\text{NaOH}$	(397)

**Boron**

Formula	State	Q, kJ	Method	Lit.
B.....	amorp.	0	Def.	
$\text{BO}_2^-$ .....	aq.	729	$\text{NaBO}_2$ ; &	(940)
$\text{BO}_3^{3-}$ .....	aq.	900	$\text{Na}_2\text{BO}_3$	



Formula	State	Q, kj	Method	Lit.
<b>Boron.—(Continued)</b>				
B <sub>2</sub> O <sub>3</sub>	c (?)	1171	+ KOH	(86, 88)
B <sub>4</sub> O <sub>7</sub>	aq.	1202	= H <sub>2</sub> BO <sub>3</sub>	
B <sub>4</sub> O <sub>7</sub>	aq.	2668	Na <sub>2</sub> B <sub>4</sub> O <sub>7</sub>	
H <sub>3</sub> BO <sub>3</sub>	c	1053	-22.6 <sup>18</sup> <sub>400</sub>	(86, 88, 976)
	aq.	1030	BCl <sub>3</sub> + H <sub>2</sub> O	
BF <sub>3</sub>	gas	1075	102	(496)
	aq.	1178	H <sub>3</sub> BO <sub>3</sub> + HF	(976)
BF <sub>4</sub> <sup>-</sup>	aq.	1498	N = HCl	
HBFB <sub>4</sub>	aq.	1498	H <sub>3</sub> BO <sub>3</sub> + HF	(740, 976)
BCl <sub>3</sub>	gas	373	B + Cl <sub>2</sub>	(84, 998)
	liq.	392	gas	(84)
BBr <sub>3</sub>	liq.	179	350 <sub>400</sub>	(84)
(NH <sub>4</sub> )BO <sub>2</sub>	200	863	N	(80)
	1320	862.0	dil.	(80)
(NH <sub>4</sub> ) <sub>2</sub> HBO <sub>3</sub>	300	1241	N	(80)
(NH <sub>4</sub> ) <sub>2</sub> BO <sub>3</sub>	aq.	1327	N	(80)

<b>Aluminum<sup>a</sup></b>				
Al(α)	c	0	Def.	
Al(β)	c		Tr.: 0.39 <sup>850</sup> <sub>(α)</sub>	(610, 611)
Al <sup>+++</sup>	aq.	529	AlCl <sub>3</sub>	
Al <sub>2</sub> O <sub>3</sub> (corundum)	c	1676	+ Na <sub>2</sub> O <sub>3</sub>	(716)
Al <sub>2</sub> O <sub>3</sub> (powder)	amorp.	1630	Al + O <sub>2</sub> ; &	(27, 143, 363, 730.5)
Al(OH) <sub>3</sub>	ppt.	1275	AlCl <sub>3</sub> + NH <sub>4</sub> OH	(32, 84, 976)
AlF <sub>3</sub>	c	1377	analogy	(32)
	aq.	1507	AlCl <sub>3</sub> + HF	(794)
AlF <sub>6</sub> <sup>-</sup>	aq.	2474	K <sub>2</sub> AlF <sub>6</sub>	
H <sub>2</sub> AlF <sub>6</sub>	aq.	2467.5	AlF <sub>3</sub> + HF	(48.1, 794)
AlF <sub>3</sub> ·5H <sub>2</sub> O	c	1571	107HF(26%)	(32)
AlF <sub>3</sub> ·3H <sub>2</sub> O(soluble)	c	2516	-6.9 <sup>15</sup>	(32)
AlF <sub>3</sub> ·3H <sub>2</sub> O(insoluble)	c	2518	+ HF	(32)
AlCl <sub>3</sub>	c	698	326	(31, 32, 84, 900, 976)
	600	1024	Al + HCl	(188, 869, 923, 976)
AlCl <sub>3</sub> ·6H <sub>2</sub> O	c	2686	55 <sup>16</sup> <sub>450</sub>	(900)
AlBr <sub>3</sub>	c	530	357 <sup>9</sup> <sub>3000</sub>	(84)
	aq.	887	+ NH <sub>4</sub> OH	(84, 881)
AlI <sub>3</sub>	c	298	372 <sup>9</sup> <sub>2300</sub>	(84)
	aq.	671	+ KCl	(84)
Al <sub>2</sub> S <sub>3</sub>	c	1443	314	(897)
Al <sub>2</sub> (SO <sub>4</sub> ) <sub>3</sub>	c	2996	dissoc.*	(1688*)
	aq.	3699	+ BaCl <sub>2</sub>	(316, 976)
Al <sub>2</sub> (SO <sub>4</sub> ) <sub>3</sub> ·6H <sub>2</sub> O	c	5181	234	(359)
Al <sub>2</sub> (SO <sub>4</sub> ) <sub>3</sub> ·18H <sub>2</sub> O	c	8816	34	(359)
AlCl <sub>3</sub> ·SO <sub>2</sub>	c	1030	312.4	(32)
AlCl <sub>3</sub> ·5SO <sub>2</sub>	c	870	315.0	(32)
AlCl <sub>3</sub> ·5H <sub>2</sub> S	c	729	315.0 <sup>15</sup> <sub>1200</sub>	(32)
AlN	c	550	+ O <sub>2</sub>	(364, 365, 662)
AlF <sub>3</sub> ·2NH <sub>4</sub> F·1½H <sub>2</sub> O	c	2894.8	-35.7	(32)
AlCl <sub>3</sub> ·NH <sub>3</sub>	c	904	228 <sup>15</sup>	(32)
AlCl <sub>3</sub> ·NH <sub>4</sub> Cl	c	1069	253.1 <sup>15</sup> <sub>800</sub>	(32)
AlCl <sub>3</sub> ·3NH <sub>3</sub>	c	1183	126.8 <sup>15</sup>	(32)
AlCl <sub>3</sub> ·5NH <sub>3</sub>	c	1435	37.9 <sup>15</sup> <sub>2300</sub>	(32)
AlCl <sub>3</sub> ·6NH <sub>3</sub>	c	1527	26.6 <sup>15</sup> <sub>2500</sub> ; &	(32, 343*)
AlCl <sub>3</sub> ·NH <sub>4</sub> Cl·6NH <sub>3</sub>	c	1905	-11.5	(32)
AlCl <sub>3</sub> ·9NH <sub>3</sub>	c	1764	33.2; &	(32)
NH <sub>4</sub> Al(SO <sub>4</sub> ) <sub>2</sub> ·12H <sub>2</sub> O	c	5900	-40 <sup>11</sup> <sub>1000</sub>	(359)
Al <sub>2</sub> C <sub>3</sub>	c	341	+ O <sub>2</sub>	(143, 1104)
Al <sub>2</sub> O <sub>3</sub> ·SiO <sub>2</sub> (andalusite)	c	2311.8	+ HF	(756)
Al <sub>2</sub> O <sub>3</sub> ·SiO <sub>2</sub> (diathene)	c	2309.9	+ HF	(756)
Al <sub>2</sub> O <sub>3</sub> ·SiO <sub>2</sub> (sillimanite)	c	2321.4	+ HF	(756)
Al <sub>2</sub> O <sub>3</sub> ·2SiO <sub>2</sub> (from kaolinite)	amorp.	410e	C + O <sub>2</sub>	(276)
Al <sub>2</sub> O <sub>3</sub> ·2SiO <sub>2</sub> ·H <sub>2</sub> O(kaolinite)	amorp.	3955	C + O <sub>2</sub>	(276)
3Al <sub>2</sub> O <sub>3</sub> ·2SiO <sub>2</sub> (mullite)	c	6127	+ HF	(756)
Al <sub>2</sub> Ti <sub>2</sub>	c	218e	+ O <sub>2</sub>	(1038)
AlCl <sub>3</sub> ·½ZnCl <sub>2</sub>	c	993	393	(32)
AlCu	c	28e(?)	+ Br <sub>2</sub>	(879)
AlCu <sub>2</sub>	c	10e	+ Br <sub>2</sub>	(879)
Al <sub>2</sub> Cu	c	39e	+ Br <sub>2</sub>	(879, 881)
AlCl <sub>3</sub> ·AgCl	c	834	317	(32)
Al <sub>2</sub> Fe	c	105	155eHCl(a)	(186)
AlCo	c	134	445HCl(a)	(186)
Al <sub>2</sub> Co	c	360	2368HCl(a)	(186)

<sup>a</sup> AlCl<sub>3</sub> in liq. COCl<sub>2</sub> (446).

Formula	State	Q, kj	Method	Lit.
<b>Yttrium</b>				
Yt	c	0	Def.	
Yt <sup>+++</sup>		Q		
YtCl <sub>3</sub>	c	306 + Q	189.9 <sup>16</sup> <sub>200</sub>	(677)
	aq.	496 + Q	ions	
Yt <sub>2</sub> (SO <sub>4</sub> ) <sub>3</sub>	aq.	2586 + 2Q	+ BaCl <sub>2</sub>	(976)
Yt <sub>2</sub> (SO <sub>4</sub> ) <sub>3</sub> ·8H <sub>2</sub> O	c	4830 + 2Q	44.7 <sup>10</sup> <sub>1200</sub>	(976)
Yt(OH) <sub>3</sub>	ppt.	711 + Q	Yt <sub>2</sub> (SO <sub>4</sub> ) <sub>3</sub> + Ba(OH) <sub>2</sub>	(976)

<b>Lanthanum</b>				
La	c	0	Def.	
La <sup>+++</sup>	aq.	751	LaCl <sub>3</sub>	
La <sub>2</sub> O <sub>3</sub>	c	1912	La + O <sub>2</sub>	(597, 730.5, 752)
La <sub>2</sub> O <sub>3</sub> ("uncondensed")	amorp.	188e	analogy	
La <sub>2</sub> O <sub>3</sub> (hydrated)	amorp.	2010	352 <sup>16</sup> <sub>(HCl100)</sub> ; &	(677, 976)
La <sub>2</sub> H <sub>3</sub>	c	670	+ HCl	(919)
LaCl <sub>3</sub>	c	1116	131 <sup>16</sup> <sub>1200</sub>	(677)
	aq.	1247	La <sub>2</sub> O <sub>3</sub> + HCl	(677)
LaS <sub>2</sub>	c	678	133HCl	(179)
LaS <sub>3</sub>	c	1328	300HCl	(179)
La <sub>2</sub> (SO <sub>4</sub> ) <sub>3</sub>	aq.	4131	+ BaCl <sub>2</sub>	(976)
La <sub>2</sub> (SO <sub>4</sub> ) <sub>3</sub> ·8H <sub>2</sub> O	c	6403	17 <sup>8</sup> <sub>2400</sub>	(976)
LaAl <sub>3</sub>	c	900(?)	+ O <sub>2</sub>	(751)

<b>Praseodymium</b>				
Pr	c	0	Def.	
Pr <sup>+++</sup>	aq.	650	PrCl <sub>3</sub>	(751)
PrO <sub>2</sub>	c	900	180HNO <sub>3</sub> (s)	(1103)
Pr <sub>2</sub> O <sub>3</sub>	c	1745	Pr + O <sub>2</sub>	(751)
Pr <sub>2</sub> O <sub>3</sub>	c	535s	1130HNO <sub>3</sub> (s)	(1103)
	amorp.	172e	analogy	(751)
PrCl <sub>3</sub>	c	1006	140 <sup>16</sup> <sub>2500</sub>	(675)
	aq.	1146	Pr <sub>2</sub> O <sub>3</sub> (amorp.) + HCl	(675)
PrCl <sub>3</sub> ·H <sub>2</sub> O	c	1311	121 <sup>17</sup> <sub>2000</sub>	(675)
PrCl <sub>3</sub> ·7H <sub>2</sub> O	c	3127	22 <sup>17</sup> <sub>2000</sub>	(675)
Pr(NO <sub>3</sub> ) <sub>3</sub>	aq.	132e	Pr <sub>2</sub> O <sub>3</sub> + HNO <sub>3</sub>	(1103)

<b>Samarium</b>				
Sa	c	0	Def.	
Sa <sup>+++</sup>	aq.	Q		
Sa <sub>2</sub> O <sub>3</sub>	c	462 + Q	+ HCl	(675)
Sa <sub>2</sub> O <sub>3</sub> (from oxalate)	amorp.	462 + Q	+ HCl	(675)
SaCl <sub>3</sub>	c	339 + Q	156 <sub>300</sub>	(675)
	aq.	495 + Q	ions	(675)
SaCl <sub>3</sub> ·NH <sub>3</sub>	c	471 + Q	dissoc.*	(689*)
SaCl <sub>3</sub> ·2NH <sub>3</sub>	c	586 + Q	dissoc.*	(689*)
SaCl <sub>3</sub> ·3NH <sub>3</sub>	c	695 + Q	dissoc.*	(689*)
SaCl <sub>3</sub> ·4NH <sub>3</sub>	c	798 + Q	dissoc.*	(689*)
SaCl <sub>3</sub> ·5NH <sub>3</sub>	c	894 + Q	dissoc.*	(689*)
SaCl <sub>3</sub> ·8NH <sub>3</sub>	c	1173 + Q	dissoc.*	(689*)
SaCl <sub>3</sub> ·9½NH <sub>3</sub>	c	1305 + Q	dissoc.*	(689*)
SaCl <sub>3</sub> ·10½NH <sub>3</sub>	c	1473 + Q	dissoc.*	(689*)

<b>Neodymium</b>				
Nd	c	0	Def.	
Nd <sup>+++</sup>	aq.	686	NdCl <sub>3</sub>	
Nd <sub>2</sub> O <sub>3</sub>	c	1820	Nd + O <sub>2</sub>	(751)
	amorp.	179e	analogy	
NdCl <sub>3</sub>	c	1032	149 <sub>300</sub>	(674)
	aq.	1181	Nd <sub>2</sub> O <sub>3</sub> (amorp.) + HCl	(674)
NdI <sub>3</sub>	c	650	205 <sup>19</sup> <sub>2000</sub>	(674)
	aq.	855	Nd <sub>2</sub> O <sub>3</sub> + HI	(675)
Nd <sub>2</sub> S <sub>3</sub>	c	1099	+ HCl	(675)
Nd <sub>2</sub> (SO <sub>4</sub> ) <sub>3</sub>	c	3848	153 <sub>300</sub>	(675)
	aq.	4001	H <sub>2</sub> SO <sub>4</sub> + Nd <sub>2</sub> O <sub>3</sub>	(675, 976)
Nd <sub>2</sub> (SO <sub>4</sub> ) <sub>3</sub> ·5H <sub>2</sub> O	c	5397	35	(675)
Nd <sub>2</sub> (SO <sub>4</sub> ) <sub>3</sub> ·8H <sub>2</sub> O	c	6262	28 <sub>300</sub>	(675, 976)
NdCl <sub>3</sub> ·NH <sub>3</sub>	c	1163	dissoc.*	(690*)
NdCl <sub>3</sub> ·2NH <sub>3</sub>	c	1279	dissoc.*	(690*)
NdCl <sub>3</sub> ·4NH <sub>3</sub>	c	1486	dissoc.*	(690*)
NdCl <sub>3</sub> ·5NH <sub>3</sub>	c	1584	dissoc.*	(690*)
NdCl <sub>3</sub> ·8NH <sub>3</sub>	c	1862	dissoc.*	(690*)
NdCl <sub>3</sub> ·11NH <sub>3</sub>	c	2118	dissoc.*	(690*)
NdCl <sub>3</sub> ·12NH <sub>3</sub>	c	2200	dissoc.*	(690*)



Formula	State	Q, kj	Method	Lit.
<b>Erbium<sup>a</sup></b>				
<b>Cerium<sup>b</sup></b>				
Ce.....	c	0	Def.	
CeO <sub>2</sub> .....	c	983	Ce + O <sub>2</sub>	(520, 730.5, 752)
Ce <sup>+++</sup> .....	aq.	690	CeCl <sub>3</sub>	
CeCl <sub>3</sub> .....	60	1178	Ce + HCl <sub>30</sub>	(194)
	600	1186	analogy	(194)
Ce <sub>2</sub> (SO <sub>4</sub> ) <sub>3</sub> .....	aq.	3318	+ BaCl <sub>2</sub>	(976)
Ce <sub>2</sub> (SO <sub>4</sub> ) <sub>3</sub> ·4½H <sub>2</sub> O.....	c		67.5	(976)
CeAl <sub>3</sub> .....	c	166	2596HCl(s); &	(194, 751)
CeAl.....	c	92	2496HCl(s); &	(194, 751)
<b>Beryllium</b>				
Be.....	c	0	Def.	
Be <sup>++</sup> .....	aq.	354	BeCl <sub>2</sub>	
BeO (low temp.).....	c	591	Be + HF	(298, 299, 687, 700)
Be(OH) <sub>2</sub> .....	ppt.	865	+ HCl; &	(687, 740, 794, 976)
BeF <sub>2</sub> .....	aq.	1007.9	BeCl <sub>2</sub> + AgF	(794)
H <sub>2</sub> BeF <sub>4</sub> .....	aq.	1643.0	Be + HF	(298)
BeCl <sub>2</sub> .....	c	471	Be + Cl <sub>2</sub>	(700)
	aq.	685	214	(687, 824)
	HCl·9H <sub>2</sub> O	656	185	(1082)
BeCl <sub>2</sub> ·4H <sub>2</sub> O.....	c	787	dissoc.*	(1082*)
BeBr <sub>2</sub> .....	c	378	233HCl(g)	(1082)
BeI <sub>2</sub> .....	c	282	262HCl(g)	(1082)
BeSO <sub>4</sub> .....	c	1157	144NaOH;* &	(596, 664, † 665.5, 687)
	aq.	1235	+ BaCl <sub>2</sub>	(687, 976)
BeSO <sub>4</sub> ·H <sub>2</sub> O.....	c	1460	+ H <sub>2</sub> O*	(596)
BeSO <sub>4</sub> ·2H <sub>2</sub> O.....	c	1715	8.0 <sup>15</sup> <sub>1000</sub>	(596, 687)
BeSO <sub>4</sub> ·4H <sub>2</sub> O.....	c	2375	4.6	(596, 687, 824, 976)
Be(NO <sub>3</sub> ) <sub>2</sub> .....	aq.	773	BeSO <sub>4</sub> + Ba(NO <sub>3</sub> ) <sub>2</sub>	(687)
BeCl <sub>2</sub> ·2NH <sub>3</sub> .....	c	982	dissoc.*	(1082*)
BeCl <sub>2</sub> ·4NH <sub>3</sub> .....	c	1225	120HCl(g)	(1082*)
BeCl <sub>2</sub> ·6NH <sub>3</sub> .....	c	1384	dissoc.*	(1082*)
BeCl <sub>2</sub> ·12NH <sub>3</sub> .....	c	1849	dissoc.*	(1082*)
BeBr <sub>2</sub> ·4NH <sub>3</sub> .....	c	1162	141HCl(g)	(1082*)
BeBr <sub>2</sub> ·6NH <sub>3</sub> .....	c	1321	dissoc.*	(1082*)
BeBr <sub>2</sub> ·10NH <sub>3</sub> .....	c	1625	dissoc.*	(1082*)
BeI <sub>2</sub> ·4NH <sub>3</sub> .....	c	1085	146HCl(g)	(1082*)
BeI <sub>2</sub> ·6NH <sub>3</sub> .....	c	1257	dissoc.*	(1082*)
BeI <sub>2</sub> ·13NH <sub>3</sub> .....	c	1807	dissoc.*	(1082*)
<b>Magnesium</b>				
Mg.....	c	0	Def.	
Mg <sup>++</sup> .....	aq.	461.2	MgCl <sub>2</sub>	
MgO (bomb).....	amorp. (?)	610	Mg + O <sub>2</sub> ; &	(315, 666, 674, 730.5, 877, 1028)
Mg(OH) <sub>2</sub> .....	ppt.	915	MgSO <sub>4</sub> + NaOH	(976, 1089)
Mg(OH) <sub>2</sub> (brucite).....	c	935	+ Na <sub>2</sub> O <sub>2</sub>	(717)
MgF <sub>2</sub> .....	ppt.	1104	MgCl <sub>2</sub> + AgF; &	(404, 465, 792)
MgCl <sub>2</sub> .....	c	641	150.6 <sup>18</sup> <sub>300</sub>	(187.5, 976)
	400	791.5	Mg + HCl	(166, 808, 869, 933, 960, 976)
	200	791.0	dil.	(324, 976)
	100	790.2	dil.	
	50	789.0	dil.	
	20	785.5	dil.	
	10	775.5	dil.	
MgCl <sub>2</sub> ·2H <sub>2</sub> O.....	c	1278	85 <sup>18</sup> <sub>300</sub>	(900, 976)
MgCl <sub>2</sub> ·4H <sub>2</sub> O.....	c	1894	42 <sup>18</sup> <sub>300</sub>	(900, 976)
MgCl <sub>2</sub> ·6H <sub>2</sub> O.....	c	2495.8	12.3 <sup>18</sup> <sub>300</sub> ; &	(822, 833, 976)
MgCl <sub>2</sub> ·MgO.....	c	1762	61HCl	(11)
MgCl <sub>2</sub> ·MgO·6H <sub>2</sub> O.....	c	3379	151HCl	(11)
MgCl <sub>2</sub> ·MgO·16H <sub>2</sub> O.....	c	6310	92HCl	(11)

<sup>a</sup> 2Er(C<sub>2</sub>H<sub>3</sub>O<sub>2</sub>)<sub>2</sub>(1500) + 3Ba(OH)<sub>2</sub>(400); ΔQ<sup>18</sup> = 107.5 (976). Er(C<sub>2</sub>H<sub>3</sub>O<sub>2</sub>)<sub>2</sub>·4H<sub>2</sub>O + 1500H<sub>2</sub>O; ΔQ<sup>20</sup> = 5.7 (976).

<sup>b</sup> Mischmetall, 40% CeO<sub>2</sub>, heat of combustion 1 g = 6.926 kj (752).

Formula	State	Q, kj	Method	Lit.
<b>Magnesium.—(Continued)</b>				
MgOHCl.....		804	MgCl <sub>2</sub> + H <sub>2</sub> O*	(720*)
MgBr <sub>2</sub> .....	c	519	181 <sup>18</sup>	(42)
	400	700	ions	
MgI <sub>2</sub> .....	c	363	208	(42)
	aq.	572	ions; &	(976)
MgS.....	c	344	159 <sup>13</sup> HCl	(697)
MgSO <sub>4</sub> .....	c	998	70.6 <sup>13</sup> HCl	(502)
MgSO <sub>4</sub> ·3H <sub>2</sub> O.....	c	1922	4.9 <sup>18</sup> HCl	(502)
MgSO <sub>4</sub> ·6H <sub>2</sub> O.....	c	2809	-23.6 <sup>14</sup> HCl	(502)
MgSO <sub>4</sub> .....	c	1260	85 <sup>18</sup> <sub>400</sub>	(187.5, 488, 506, 510, 665.5, 976)
	400	1344.8	dil.	
	200	1344.6	MgSO <sub>4</sub> + BaCl <sub>2</sub>	(976)
	100	1344.3	dil.	(976)
	50	1344.2	dil.	
	20	1343.0	dil.	
MgSO <sub>4</sub> ·H <sub>2</sub> O.....	c	1575	56 <sup>18</sup> <sub>400</sub>	(360, 506, 976)
MgSO <sub>4</sub> ·2H <sub>2</sub> O.....	c	1871.0	46.2 <sup>18</sup> <sub>400</sub>	(976)
MgSO <sub>4</sub> ·4H <sub>2</sub> O.....	c	2471.7	17.7 <sup>18</sup> <sub>400</sub>	(976)
MgSO <sub>4</sub> ·6H <sub>2</sub> O.....	c	3062.2	-0.0 <sup>18</sup> <sub>400</sub>	(976)
MgSO <sub>4</sub> ·7H <sub>2</sub> O.....	c	3364.1	-16.2 <sup>18</sup> <sub>400</sub>	(187.5, 312, † 429, 458, 506, 507, 510, 580, 590, 976)
Mg <sub>2</sub> O.....	aq.	1608	MgSO <sub>4</sub> + BaSO <sub>4</sub>	(976)
Mg <sub>2</sub> O·6H <sub>2</sub> O.....	c	3337	-12.4 <sup>19</sup> <sub>400</sub>	(976)
Mg(HS) <sub>2</sub> .....	aq.	491	Mg(OH) <sub>2</sub> + H <sub>2</sub> S	(976)
Mg <sub>3</sub> N <sub>2</sub> .....	c	495	+ HCl; &	(680, 735)
Mg(NO <sub>3</sub> ) <sub>2</sub> .....	400	876.8	Ba(NO <sub>3</sub> ) <sub>2</sub> + MgSO <sub>4</sub>	(976)
	200	876.5	dil.	(224, † 976)
	100	876.5	dil.	
	50	876.7	dil.	
	20	876.7	dil.	
	15	876.1	dil.	
	12	875.0	dil.	
Mg(NO <sub>3</sub> ) <sub>2</sub> ·6H <sub>2</sub> O.....	c	2611	-17.7 <sup>18</sup> <sub>400</sub>	(811, 976)
(Mg(NH <sub>2</sub> ) <sub>2</sub> ) <sup>++</sup> .....	aq.	622	Mg(NH <sub>2</sub> ) <sub>2</sub> Cl <sub>2</sub>	(128)
MgCl <sub>2</sub> ·NH <sub>3</sub> .....	c	774	dissoc.*	(192*)
MgCl <sub>2</sub> ·2NH <sub>3</sub> .....	c	906	dissoc.*	(192*)
	aq.	953	mix.	(128)
MgCl <sub>2</sub> ·6NH <sub>3</sub> .....	c	1263	dissoc.;* &	(192, 222, 323*)
MgBr <sub>2</sub> ·NH <sub>3</sub> .....	c	655	dissoc.*	(192*)
MgBr <sub>2</sub> ·2NH <sub>3</sub> .....	c	785	dissoc.*	(192*)
MgBr <sub>2</sub> ·6NH <sub>3</sub> .....	c	1223	dissoc.*	(234*)
MgI <sub>2</sub> ·2NH <sub>3</sub> .....	c	645	dissoc.*	(192, 234*)
MgI <sub>2</sub> ·6NH <sub>3</sub> .....	c	1116	dissoc.*	(192, 234*)
MgSO <sub>4</sub> ·(NH <sub>4</sub> ) <sub>2</sub> SO <sub>4</sub> ·2H <sub>2</sub> O.....	c	3885	+ 4H <sub>2</sub> O	(262)
MgSO <sub>4</sub> ·(NH <sub>4</sub> ) <sub>2</sub> SO <sub>4</sub> ·6H <sub>2</sub> O.....	c	4254	-41	(458)
3MgSO <sub>4</sub> ·(NH <sub>4</sub> ) <sub>2</sub> SO <sub>4</sub> ·6H <sub>2</sub> O.....	c	5757	+37.1HCl(300)	(502)
3MgSO <sub>4</sub> ·(NH <sub>4</sub> ) <sub>2</sub> SO <sub>4</sub> ·18H <sub>2</sub> O.....	c	9321	-93.2HCl(300)	(502)
Mg <sub>3</sub> (PO <sub>4</sub> ) <sub>2</sub> .....	coll.	3830 (?)	MgSO <sub>4</sub> + Na <sub>2</sub> PO <sub>4</sub>	(129)
MgHPO <sub>4</sub> .....	coll.	1740	MgSO <sub>4</sub> + Na <sub>2</sub> HPO <sub>4</sub>	(129)
Mg(NH <sub>4</sub> )PO <sub>4</sub> ·6H <sub>2</sub> O.....	c	3773	Mg(NH <sub>4</sub> ) <sub>2</sub> Cl <sub>2</sub> + Na <sub>2</sub> HPO <sub>4</sub>	(129)
MgHAsO <sub>4</sub> .....	aq.	1351	N	(202)
MgH <sub>2</sub> (AsO <sub>4</sub> ) <sub>2</sub> .....	aq.	2263	N	(202)
Mg <sub>2</sub> (AsO <sub>4</sub> ) <sub>3</sub> .....	c	3061	N	(202)
Mg(NH <sub>4</sub> )AsO <sub>4</sub> ·6H <sub>2</sub> O.....	c	3197	Mg(NH <sub>4</sub> ) <sub>2</sub> Cl <sub>2</sub> + H <sub>2</sub> AsO <sub>4</sub>	(129)
MgCO <sub>3</sub> .....	c	1119	MgSO <sub>4</sub> + Na <sub>2</sub> CO <sub>3</sub>	(58, 662, 1004*)
MgCN <sub>2</sub> .....	c	248	+ O <sub>2</sub>	(427)
Mg(CN) <sub>2</sub> .....	aq.	169	Ba(CN) <sub>2</sub> + MgSO <sub>4</sub>	(1007)



Formula	State	Q, kj	Method	Lit.
<b>Magnesium.—(Continued)</b>				
MgSiO <sub>3</sub> .....	c	1450	MgO + SiO <sub>2</sub>	(275)
Mg <sub>2</sub> Sn.....	c	205	1092 FeCl <sub>2</sub> + HCl(8)	(189)
MgZn <sub>2</sub> .....	c	55	+HCl; &	(188, 881, 1020)
MgCd(II).....	c	38	+HCl; &	(188, 881)
MgCd(I).....	c		Tr.; 1.2 <sup>100.7</sup>	(881)
MgHg.....	liq.	72.4	+HCl	(960)
MgBr <sub>2</sub> .HgBr <sub>2</sub> .....	4400	868	mix.	(1012)
MgBr <sub>2</sub> .2HgBr <sub>2</sub> .....	4200	1025	mix.	(1012)
2MgBr <sub>2</sub> .HgBr <sub>2</sub> .....	4800	1576	mix.	(1012)
Mg(CN) <sub>2</sub> .Hg(CN) <sub>2</sub> .....	600	— 50	mix.	(1012)
Mg(CN) <sub>2</sub> .2Hg(CN) <sub>2</sub> .....	900	— 316	mix.	(1012)
MgCl <sub>2</sub> .2Hg(CN) <sub>2</sub> .....	1000	248	mix.	(1009)
MgCl <sub>2</sub> .2Hg(CN) <sub>2</sub> .6H <sub>2</sub> O.....	c	2008	43 <sup>15</sup>	(1009)
MgBr <sub>2</sub> .2Hg(CN) <sub>2</sub> .....	1000	161	mix.	(1009)
MgBr <sub>2</sub> .2Hg(CN) <sub>2</sub> .8H <sub>2</sub> O.....	c	2518	66.8 <sup>14</sup>	(1009)
MgI <sub>2</sub> .2Hg(CN) <sub>2</sub> .....	100	53	mix.	(1009)
MgI <sub>2</sub> .2Hg(CN) <sub>2</sub> .8H <sub>2</sub> O.....	c	2426	— 84 <sup>15</sup>	(1009)
Mg <sub>2</sub> Al <sub>2</sub> .....	c	205	+HCl; &	(188, 881)
Mg <sub>2</sub> Co.....	c	54	1090HCl(m)	(194)
Mg <sub>2</sub> Co.....	c	71	1997HCl(m)	(194)
<b>Calcium*</b>				
Ca.....	c	0	Def.	
Ca <sup>++</sup> .....	aq.	542	CaCl <sub>2</sub>	
CaO.....	c	634.9	194.4HCl; &	(436, 617, 976)
CaO(II).....	c		Tr.; 1.2 <sup>410</sup> (I)	(585, 608)
CaO(III).....	amorp.	635	194.8HCl	(67, 299, 436, 617, 674)
CaO <sub>2</sub> .....	c	652	79.2HCl	(48, 387)
CaO <sub>2</sub> .8H <sub>2</sub> O.....	c	3007	+HCl	(387)
CaH (?).....	c	80	dissoc.*	(721)
CaH <sub>2</sub> .....	c	192	346HCl; &	(280, 479, 589, 641.1, 721)
Ca(OH) <sub>2</sub> .....	c	988	128HCl	(321, 589, 662, 976)
Ca(OH) <sub>2</sub> .....	aq.	999.2	+HCl; &	(67, 386, 479, 719, 976)
Ca(OH) <sub>2</sub> .H <sub>2</sub> O <sub>2</sub> .....	c	1217	H <sub>2</sub> O <sub>2</sub> + Ca(OH) <sub>2</sub>	(387)
CaF <sub>2</sub> .....	ppt.	1198	N	(464)
CaCl.....	c	409	302 <sup>15</sup> HCl(m)	(46)
CaCl <sub>2</sub> (fused).....	c	798	75.3 <sup>15</sup> 400	(32, 187.5, 316, 360.5, 623, 811, 976)
Ca.....	∞	873.2	dil.	(324, 501.5, 976, 1003)
Ca.....	400	873.0	dil.	
Ca.....	200	873.0	Ca + HCl; &	(188, 197, 289, 299, 479, 489, 719)
Ca.....	100	872.3	dil.	
Ca.....	50	871.8	dil.	
Ca.....	20	869.3	dil.	
Ca.....	10	862.5	dil.	
Ca.....	6	854	CaCl <sub>2</sub> .6H <sub>2</sub> O	(741)
CaCl <sub>2</sub> .H <sub>2</sub> O.....	c	1110	49 <sup>15</sup> 300	(900, 976)
CaCl <sub>2</sub> .2H <sub>2</sub> O.....	c	1395	42 <sup>15</sup> 400	(750, 884, 976)
CaCl <sub>2</sub> .4H <sub>2</sub> O.....	c	2010	7.7 <sup>15</sup> 400	(750, 884, 976)
CaCl <sub>2</sub> .6H <sub>2</sub> O.....	c	2609.1	— 19.1 <sup>15</sup> 400	(312, 316, 360.5, 522, 750, 811, 884, 976)
CaCl <sub>2</sub> .4HCl.....	aq.			(801)
CaCl <sub>2</sub> .2CaO.....	c	2115	416HCl	(10)
CaCl <sub>2</sub> .3CaO.....	c	2740	616HCl	(10)
CaCl <sub>2</sub> .3CaO.3H <sub>2</sub> O.....	c	3810	409HCl; &	(10, 966)
CaCl <sub>2</sub> .3CaO.16H <sub>2</sub> O.....	c	7674	265HCl	(10)
Ca(ClO) <sub>2</sub> .....	aq.	760	ions	
CaOCl <sub>2</sub> .....	c	748	41.1	(768)
CaOCl <sub>2</sub> .....	aq.	789	+H <sub>2</sub> O <sub>2</sub> ; &	(835)
CaOCl <sub>2</sub> .H <sub>2</sub> O.....	c	1043	31.5	(535, 759, 764, 768)

Formula	State	Q, kj	Method	Lit.
<b>Calcium.—(Continued)</b>				
CaBr <sub>2</sub> .....	c	679	102	(611, 976, 1009)
CaBr <sub>2</sub> .....	aq.	782	ions	
CaBr <sub>2</sub> .6H <sub>2</sub> O.....	c	2503	— 4.6 <sup>10</sup> 400	(976)
CaBr <sub>2</sub> .3CaO.3H <sub>2</sub> O.....	c	3718	409 <sup>15</sup> HBr	(964)
CaBr <sub>2</sub> .3CaO.16H <sub>2</sub> O.....	c	7581	266.0 <sup>10</sup> HBr	(966)
CaI <sub>2</sub> .....	c	538	115.9 <sup>15</sup> 400	(411, 811, 976)
CaI <sub>2</sub> .....	aq.	654	ions	
CaI <sub>2</sub> .8H <sub>2</sub> O.....	c	2936	7.3 <sup>20</sup>	(966)
CaI <sub>2</sub> .3CaO.16H <sub>2</sub> O.....	c	7450	265HI	(966)
CaS.....	c	475	110.0 <sup>11</sup> HCl	(897)
CaSO <sub>2</sub> .2H <sub>2</sub> O.....	aq.	501	N	(796)
CaSO <sub>2</sub> (anhydrite).....	c	1731	+S	(178)
CaSO <sub>2</sub> (soluble).....	c	1405	22	(396, 717)
CaSO <sub>2</sub> (soluble).....	c	1416.0	11.1	(396, 523, 717)
CaSO <sub>4</sub> .H <sub>2</sub> O.....	aq.	1427	N; &	(976)
CaSO <sub>4</sub> .H <sub>2</sub> O.....	c	1555	15	(266, 396, 523)
CaSO <sub>4</sub> .2H <sub>2</sub> O.....	c	1999.6	— 1	(30, 602.5, 976)
CaS <sub>2</sub> O <sub>8</sub> .....	∞	1132	ions	
CaS <sub>2</sub> O <sub>8</sub> .....	350	1132.2	dil.	(178)
CaS <sub>2</sub> O <sub>8</sub> .....	230	1132.1	dil.	
CaS <sub>2</sub> O <sub>8</sub> .....	116	1131.5	dil.	
CaS <sub>2</sub> O <sub>8</sub> .....	33.5	1130.4	dil.	
CaS <sub>2</sub> O <sub>8</sub> .....	aq.	1688.4	ions	
CaS <sub>2</sub> O <sub>8</sub> .4H <sub>2</sub> O.....	c	2866	— 33.3 <sup>15</sup> 400	(976)
Ca(HS) <sub>2</sub> .....	aq.	575	N	(976)
CaI <sub>2</sub> .4SO <sub>2</sub> .....	c	1876	dissoc.*	(342)
CaSe.....	c	370	146HCl	(380)
CaN <sub>2</sub> .....	c	— 317	dissoc.	(1113)
Ca <sub>2</sub> N <sub>2</sub> .....	c	456	1432HCl; &	(478, 479, 735)
Ca(NO <sub>2</sub> ) <sub>2</sub> .4H <sub>2</sub> O.....	c	1697	+Br <sub>2</sub>	(123)
Ca(NO <sub>2</sub> ) <sub>2</sub> .....	c	943	16.5 <sup>15</sup> 400	(55, 360.5, 811, 976)
Ca(NO <sub>2</sub> ) <sub>2</sub> .....	400	959	ions	(324, 800)
Ca(NO <sub>2</sub> ) <sub>2</sub> .....	4	961	→Ca(NO <sub>2</sub> ) <sub>2</sub> . 4H <sub>2</sub> O	(732, 813)
Ca(NO <sub>2</sub> ) <sub>2</sub> .2H <sub>2</sub> O.....	c	1540	dissoc.*	(621)
Ca(NO <sub>2</sub> ) <sub>2</sub> .3H <sub>2</sub> O.....	c	1840	dissoc.*	(621)
Ca(NO <sub>2</sub> ) <sub>2</sub> .4H <sub>2</sub> O.....	c	2134	— 30.3 <sup>15</sup> 400	(55, 360.5, 811, 976)
Ca(NH <sub>2</sub> ) <sub>2</sub> .....	c	382.9	426 <sup>15</sup> HCl(m)	(480)
Ca(NO <sub>2</sub> ) <sub>2</sub> .Ca(OH) <sub>2</sub> .....	c	1935	141HNO <sub>3</sub>	(1044)
Ca(NO <sub>2</sub> ) <sub>2</sub> .Ca(OH) <sub>2</sub> . 2H <sub>2</sub> O.....	c	2886	104HNO <sub>3</sub>	(1044)
CaCl <sub>2</sub> .NH <sub>3</sub> .....	c	914	dissoc.*	(827)
CaCl <sub>2</sub> .2NH <sub>3</sub> .....	c	1023	dissoc.* &	(827, 839)
CaCl <sub>2</sub> .4NH <sub>3</sub> .....	c	1201	+HCl; &	(827, 839)
CaCl <sub>2</sub> .8NH <sub>3</sub> .....	c	1550	+HCl; &	(824, 827, 839)
CaBr <sub>2</sub> .NH <sub>3</sub> .....	c	803	dissoc.*	(827, 839)
CaBr <sub>2</sub> .2NH <sub>3</sub> .....	c	920	dissoc.*	(827, 839)
CaBr <sub>2</sub> .4NH <sub>3</sub> .....	c	1299	dissoc.*	(827, 839)
CaBr <sub>2</sub> .8NH <sub>3</sub> .....	c	1473	dissoc.*	(827, 839)
CaI <sub>2</sub> .NH <sub>3</sub> .....	c	666	dissoc.*	(827, 839)
CaI <sub>2</sub> .2NH <sub>3</sub> .....	c	792	dissoc.*	(827, 839)
CaI <sub>2</sub> .6NH <sub>3</sub> .....	c	1209	dissoc.*	(827, 839)
CaI <sub>2</sub> .8NH <sub>3</sub> .....	c	1371	dissoc.*	(827, 839)
CaSO <sub>4</sub> (NH <sub>4</sub> ) <sub>2</sub> SO <sub>4</sub> .H <sub>2</sub> O.....	c	2877.4	— 9.0	(30)
2CaSO <sub>4</sub> (NH <sub>4</sub> ) <sub>2</sub> SO <sub>4</sub> .....	c	3991	18.3	(30)
5CaSO <sub>4</sub> (NH <sub>4</sub> ) <sub>2</sub> SO <sub>4</sub> .H <sub>2</sub> O.....	c	8570	9.7	(30)
Ca <sub>2</sub> (PO <sub>4</sub> ) <sub>3</sub> .....	c	4110	Na <sub>2</sub> PO <sub>4</sub> + CaCl <sub>2</sub> ; &	(86, 88, 129, 569)
CaHPO <sub>4</sub> .....	coll.	4090	N	(86, 88, 129, 569)
CaHPO <sub>4</sub> .....	ppt.	1810	N; &	(86, 88, 129, 569)
CaHPO <sub>4</sub> .2H <sub>2</sub> O.....	c	2393	Na <sub>2</sub> HPO <sub>4</sub> + CaCl <sub>2</sub>	(86, 88, 129, 569)
CaH <sub>2</sub> (PO <sub>4</sub> ) <sub>2</sub> .....	ppt.	3110	N	
Ca <sub>2</sub> (AsO <sub>4</sub> ) <sub>3</sub> .....	ppt.	3320	N	(86, 88, 129, 569)
CaHAsO <sub>4</sub> .....	ppt.	1430	N	(201)

\* Wollastonite to pseudowollastonite (?) heat of reversion, 1.16 cal per mol (8). Cement, "heat of burning" (753).



Formula	State	Q, kj	Method	Lit.	Formula	State	Q, kj	Method	Lit.
Calcium.—(Continued)					Strontium <sup>a</sup>				
$\text{CaH}_2(\text{AsO}_4)_2$	ppt.	2340	N	(201)	Sr	c	0	Def.	
$\text{CaC}_2$	c	61	254.0HCl	(379, 427, 595, 594.5)	$\text{Sr}^{++}$	aq.	545	$\text{SrCl}_2$	
$\text{CaCO}_3$	coll.	1205	$\text{CaCl}_2 + \text{Na}_2\text{CO}_3$	(61)	$\text{SrO}$	c	589	$125.5^{15}_{1100}$	(67, 400, 401, 404, 976)
$\text{CaCO}_3(\text{calcite})$	c	1209	$\text{CaCl}_2 + \text{K}_2\text{CO}_3$ ; &	(25, 58, 61, 562, * 564, 617, 976, 1075*)	$\text{SrO}_2$	c	641	$93.0^{15}_{\text{HCl (900)}}$	(385)
$\text{CaCO}_3(\text{aragonite})$	c	1207	+HCl; &	(23, 25, 612, 617)	$\text{Sr}_2\text{O}$	c	643	$732^{15}_{\text{HCl}}$	(46)
$\text{CaC}_2\text{O}_4$	ppt.	1395	$\text{K}_2\text{C}_2\text{O}_4 + \text{CaCl}_2$	(58)	$\text{SrH}_2$	c	176	$368^{15}_{\text{HCl (200)}}$	(480)
$\text{Ca}(\text{CHO}_2)_2$	c	1368	$2.8^{16}_{360}$	(55)	$\text{Sr}(\text{OH})_2$	c	957	$43.2^{15}_{1100}$ ; &	(67, 404, 976)
$\text{CaC}_4\text{H}_4\text{O}_4$	c	1795	ions; &	(55)	$\text{Sr}(\text{OH})_2 \cdot \text{H}_2\text{O}$	aq.	1001	+HCl	(67, 385, 976)
$\text{Ca}(\text{C}_2\text{H}_3\text{O}_2)_2$	c	1789	N	(56)	$\text{Sr}(\text{OH})_2 \cdot 8\text{H}_2\text{O}$	c	1264	$22.0^{15}_{1100}$	(385)
$\text{Ca}(\text{C}_2\text{H}_3\text{O}_2)_2$	c	1498	N	(56)	$\text{SrO}_2 \cdot 9\text{H}_2\text{O}$	c	3350	$-59.7^{15}_{1100}$	(67, 976, 404)
$\text{Ca}(\text{C}_2\text{H}_3\text{O}_2)_2$	c	1527	$29^{16}_{440}$	(55, 359)	$\text{SrF}_2$	ppt.	3301	$7.3^{15}_{\text{HCl (200)}}$	(385)
$\text{Ca}(\text{C}_2\text{H}_3\text{O}_2)_2 \cdot \text{H}_2\text{O}$	aq.	1789	ions; &	(55)	$\text{SrCl}$	c	446	$\text{AgF} + \text{SrCl}_2$ ; &	(464, 792)
$\text{Ca}(\text{C}_2\text{H}_3\text{O}_2)_2$	c	947	$24.5^{17}_{600}$	(55)	$\text{SrCl}_2$	c	828.0	$264^{15}_{\text{HCl (200)}}$	(46)
$\text{Ca}(\text{C}_2\text{H}_3\text{O}_2)_2 \cdot 2\text{C}_2\text{H}_5\text{OH}$	c	1534	$168^{15}_{\text{HCl (110)}}$	(415)				$46.7^{15}_{400}$	(32, 46, 157.5, 360.5, 623, 810, 976)
$3\text{CaO} \cdot 4\text{C}_2\text{H}_5\text{OH}$	c	3245	$154^{15}_{\text{HCl (110)}}$	(415)		2000	875.22	dil.	(324, 325, 653, 827)
$\text{CaCN}_2$	c	356	$389^{15}_{\text{HCl}}$	(380)		1000	875.12	dil.	
$\text{Ca}(\text{CN})_2$	aq.	253	+O <sub>2</sub> ; &	(319, 427, 576, 595, 603, 973)		500	874.78	dil.	
$3\text{CaO} \cdot \text{Ca}(\text{CN})_2 \cdot 15\text{H}_2\text{O}$	c	6729	N	(555)		200	874.7	Sr + HCl; &	(480, 483, 976)
$\text{CaSi}$	c	370	$393^{15}_{\text{HCl}}$	(555)		100	874.61	dil.	
$\text{CaSi}_2$	c	940	+O <sub>2</sub>	(1057)	$\text{SrCl}_2 \cdot 2\text{H}_2\text{O}$	50	874.57	dil.	
$\text{CaSiO}_3$	gls.	1570	+O <sub>2</sub>	(1057)	$\text{SrCl}_2 \cdot 4\text{H}_2\text{O}$	c	1438.4	$8.7^{15}_{400}$	(900)
$\text{Ca}_2\text{SiO}_4$	gls.	1810	$\text{CaCO}_3 + \text{SiO}_2$	(275, 276, 618, 619)	$\text{SrCl}_2 \cdot 6\text{H}_2\text{O}$	c	2031.6	$-12.1^{15}_{400}$	(13, * 429, * 810, 976)
$\text{CaSn}_2$	c	180	$\text{CaCO}_3 + \text{SiO}_2$	(275, 276)	$\text{SrCl}_2 \cdot \text{SrO} \cdot \text{H}_2\text{O}$	c	2623.2	$-31.4^{15}_{400}$	(55, 157.5, 360.5, 976)
$\text{CaZn}_4$	c	123	$\text{CaCO}_3 + \text{SiO}_2$	(275, 276)	$\text{SrCl}_2 \cdot \text{SrO} \cdot 9\text{H}_2\text{O}$	c	1828	$164.5^{22}_{\text{HCl (100)}}$	(11)
$\text{CaZn}_{10}$	c	201	$1180^{15}_{\text{FeCl}_2} + \text{HCl (5)}$	(169)	$\text{SrCl}_2 \cdot \text{SrO} \cdot 9\text{H}_2\text{O}$	c	4211	$70.0^{22}_{\text{HCl (100)}}$	(11)
$\text{Ca}_2\text{Zn}_3$	c	170	$919^{15}_{\text{HCl (20)}}$	(197, 881)	$\text{SrBr}_2$	c	716	$67^{15}_{400}$	(360.5, 966, 976)
$\text{CaCd}_2$	c	126	$1594^{15}_{\text{HCl (20)}}$	(197, 881)	$\text{SrBr}_2 \cdot \text{H}_2\text{O}$	aq.	784	ions	(976)
$\text{CaBr}_2 \cdot \text{HgBr}_2$	4400	950	$919^{15}_{\text{HCl (20)}}$	(197)	$\text{SrBr}_2 \cdot 2\text{H}_2\text{O}$	c	1029	$41^{15}_{400}$	(976)
$\text{CaBr}_2 \cdot 2\text{HgBr}_2$	8400	1107	$668^{15}_{\text{HCl (20)}}$	(197)	$\text{SrBr}_2 \cdot 4\text{H}_2\text{O}$	c	1330	$26^{15}_{400}$	(976)
$\text{Ca}(\text{CN})_2 \cdot \text{Hg}(\text{CN})_2$	900	33.0	mix.	(1012)	$\text{SrBr}_2 \cdot 6\text{H}_2\text{O}$	c	1928	$0^{15}_{400}$	(976)
$\text{Ca}(\text{CN})_2 \cdot 2\text{Hg}(\text{CN})_2$	900	233	mix.	(1009)	$\text{SrBr}_2 \cdot 8\text{H}_2\text{O}$	c	2528	$-27.0^{15}_{400}$	(360.5, 976)
$\text{CaCl}_2 \cdot 2\text{Hg}(\text{CN})_2$	1000	330	mix.	(1009)	$\text{SrBr}_2 \cdot \text{SrO} \cdot 3\text{H}_2\text{O}$	c	2313	$161^{15}_{\text{HBr}}$	(966)
$\text{CaCl}_2 \cdot 2\text{Hg}(\text{CN})_2 \cdot 6\text{H}_2\text{O}$	c	2108	$-61.1^{15}$	(1009)	$\text{SrBr}_2 \cdot \text{SrO} \cdot 9\text{H}_2\text{O}$	c	4122	$68.8^{20}_{\text{HBr}}$	(966)
$\text{CaBr}_2 \cdot 2\text{Hg}(\text{CN})_2$	1000	242	mix.	(1009)	$\text{SrI}_2$	c	570	$85.6^{12}$	(966)
$\text{CaBr}_2 \cdot 2\text{Hg}(\text{CN})_2 \cdot 7\text{H}_2\text{O}$	c	2328	$-82.9^{15}$	(1009)		aq.	656	ions	
$\text{CaI}_2 \cdot 2\text{Hg}(\text{CN})_2$	1000	132	mix.	(1009)	$\text{SrI}_2 \cdot 7\text{H}_2\text{O}$	c	2678	$-18.7^{15}$	(966)
$\text{CaI}_2 \cdot 2\text{Hg}(\text{CN})_2 \cdot 6\text{H}_2\text{O}$	c	1943	-94	(1009)	$\text{SrS}$	c	473	$113^{11}_{\text{HCl}}$	(897)
$\text{Ca}(\text{Ag}(\text{CN})_2)_2$	500	31	$\text{Ca}(\text{CN})_2 + \text{AgCN}$	(1011)		aq.	503	N; &	(976)
$\text{CaAgC}_2\text{N}_2$	1000	287	$\text{Ca}(\text{CN})_2 + \text{AgCN}$	(1011)	$\text{SrSO}_4$	c	1428	O; &	(30, 976)
$\text{Ca}_2\text{Fe}(\text{CN})_6$	aq.	578	N	(555)	$\text{SrS}_2\text{O}_6$	aq.	1428	N; &	(55, 279, 976)
$\text{Ca}_2\text{Fe}(\text{CN})_6 \cdot 12\text{H}_2\text{O}$	c	4031	-19 <sup>10</sup>	(555)	$\text{SrS}_2\text{O}_6 \cdot 4\text{H}_2\text{O}$	aq.	1693	ions	(976)
$\text{CaH}_2\text{Fe}(\text{CN})_6$	aq.	34	N	(555)	$\text{Sr}(\text{HS})_2$	c	2876	$-38.7^{15}_{400}$	(976)
$\text{CaO} \cdot \text{B}_2\text{O}_3$	c	1936	$94^{15}_{\text{HCl}}$	(462)	$\text{Sr}(\text{HS})_2$	aq.	577	N	(976)
$\text{CaO} \cdot 2\text{B}_2\text{O}_3$	c	3145	$87^{15}_{\text{HCl}}$		$\text{SrI}_2 \cdot 2\text{SO}_2$	c	1129	dissoc.*	(342*)
$2\text{CaO} \cdot \text{B}_2\text{O}_3$	c	2646	$213^{15}_{\text{HCl}}$		$\text{SrI}_2 \cdot 4\text{SO}_2$	c	1912	dissoc.*	(342*)
$3\text{CaO} \cdot \text{B}_2\text{O}_3$	c	3339	$348.8^{15}_{\text{HCl}}$		$\text{SrSe}$	c	377	$141^{15}_{\text{HCl}}$	(350)
$\text{CaAl}_2$	c	213	$1900^{15}_{\text{HCl (5)}}$	(197)		aq.	427	N	(350)
$\text{CaO} \cdot \text{Al}_2\text{O}_3$	gls.	2300	$\text{CaCO}_3 + \text{Al}_2\text{O}_3$	(275, 276)	$\text{SrN}_6$	c	205	dissoc.	(1113)
$2\text{CaO} \cdot \text{Al}_2\text{O}_3$	gls.	2900	$\text{CaCO}_3 + \text{Al}_2\text{O}_3$	(275, 276)	$\text{Sr}_2\text{N}_2$	c	386	$1513.5^{15}_{\text{HCl (200)}}$	(480)
$3\text{CaO} \cdot \text{Al}_2\text{O}_3$	gls.	3500	$\text{CaCO}_3 + \text{Al}_2\text{O}_3$	(275, 276)	$\text{Sr}(\text{NO})_2$	aq.	528	N; &	(56)
$3\text{CaCl}_2 \cdot 4\text{AlCl}_3$	c	5264	1451	(32)	$\text{Sr}(\text{NO})_2 \cdot 5\text{H}_2\text{O}$	c	1984	$26.8^{15}_{\text{HCl}}$	(56)
$\text{CaO} \cdot \text{Al}_2\text{O}_3 - 6\text{SiO}_2(\text{heulandite})$	c	3270	$1197^{15}_{\text{HF (50\%)}}$	(740)	$\text{Sr}(\text{NO}_2)_2$	c	981	$-19.5^{15}_{400}$	(55, 360.5, 810, 976)
$3\text{CaO} \cdot \text{Al}_2\text{O}_3 \cdot 2\text{SiO}_2$	c	6220	$\text{CaCO}_3 + \text{Al}_2\text{O}_3 + \text{SiO}_2$	(276)					
$\text{Ca}_2\text{Mg}_4$	c	180	$335^{15}_{\text{HCl (5)}}$	(188, 881)	$\text{Sr}(\text{NO}_2)_2 \cdot 4\text{H}_2\text{O}$	c	2158	$-51.5^{15}_{400}$	(55, 360.5, 810, 976)
$\text{CaCl}_2 \cdot 2\text{MgCl}_2 \cdot 2\text{H}_2\text{O}$	c	2934	$93^{15}$	(822)	$\text{Sr}(\text{NH}_4)_2$	c	346	$464^{15}_{\text{HCl (200)}}$	(480)
$\text{MgCO}_3 \cdot \text{CaCO}_3(\text{dolomite})$	c	2239	$132.1^{15}_{\text{HCl}}$	(24, 701)	$\text{Sr}(\text{NH}_4)_2$	c	516	dissoc.*	(191*)

<sup>a</sup>  $\text{SrCl}_2 + \text{HCl}$ , partial heat content of HCl (501†).



Formula	State	Q, kj	Method	Lit.
<b>Strontium.—(Continued)</b>				
SrCl <sub>2</sub> .NH <sub>3</sub>	c	915	dissoc.*	(528*)
SrCl <sub>2</sub> .8NH <sub>3</sub>	c	1571	dissoc.*	(528*)
SrBr <sub>2</sub> .NH <sub>3</sub>	c	830	dissoc.*	(528*)
SrBr <sub>2</sub> .2NH <sub>3</sub>	c	929	dissoc.*	(528*)
SrBr <sub>2</sub> .8NH <sub>3</sub>	c	1479	dissoc.*	(528*)
SrI <sub>2</sub> .NH <sub>3</sub>	c	692	dissoc.*	(528*)
SrI <sub>2</sub> .2NH <sub>3</sub>	c	803	dissoc.*	(528*)
SrI <sub>2</sub> .6NH <sub>3</sub>	c	1197	dissoc.*	(528*)
SrI <sub>2</sub> .8NH <sub>3</sub>	c	1381	dissoc.*	(528*)
SrSO <sub>4</sub> .(NH <sub>4</sub> ) <sub>2</sub> SO <sub>4</sub>	c	2594	-13.4 <sub>1000</sub>	(30)
Sr <sub>3</sub> (PO <sub>4</sub> ) <sub>2</sub>	ppt.	4100	N; &	(86, 129, 569)
SrHPO <sub>4</sub> (?)	ppt.	1820	N	(86, 129, 569)
SrH <sub>2</sub> (PO <sub>4</sub> ) <sub>2</sub> (?)	ppt.	3120	N	(86, 129, 569)
Sr <sub>2</sub> (AsO <sub>4</sub> ) <sub>2</sub>	ppt.	3330	N	(201)
SrHAsO <sub>4</sub>	ppt.	1430	N	(201)
SrH <sub>2</sub> (AsO <sub>4</sub> ) <sub>2</sub> (?)	ppt.	2340	N	(201)
SrCO <sub>3</sub>	ppt.	1210	SrCl <sub>2</sub> + Na <sub>2</sub> CO <sub>3</sub> ; &	(55, 58, 565, 976)
SrC <sub>2</sub> O <sub>4</sub> .2H <sub>2</sub> O	c	2107	N	(55)
Sr(CHO <sub>2</sub> ) <sub>2</sub>	c	1370	2.6 <sub>100</sub>	(55)
Sr(CHO <sub>2</sub> ) <sub>2</sub> .2H <sub>2</sub> O	aq.	1373	N; &	(55, 976)
Sr(C <sub>2</sub> H <sub>3</sub> O <sub>2</sub> ) <sub>2</sub>	c	1967	-22.8 <sub>100</sub>	(55, 976)
Sr(C <sub>2</sub> H <sub>3</sub> O <sub>2</sub> ) <sub>2</sub> .2H <sub>2</sub> O	c	1505	23.3 <sub>100</sub>	(55, 976)
Sr(C <sub>2</sub> H <sub>3</sub> O <sub>2</sub> ) <sub>2</sub> .4H <sub>2</sub> O	aq.	1529	N; &	(55, 976)
Sr(CN) <sub>2</sub>	c	1650	22.0 <sub>100</sub>	(55, 976)
Sr(CN) <sub>2</sub> .4H <sub>2</sub> O	aq.	254	N	(555, 976)
SrSiO <sub>3</sub>	c	1416	-17.4 <sub>100</sub>	(555)
SrHg <sub>2</sub> (co)	gl.	1520	SrCO <sub>3</sub> + SiO <sub>2</sub>	(278)
SrHg <sub>2</sub> (co)	liq.	249	NaHg + SrCl <sub>2</sub> aq.	(928*)
SrBr <sub>2</sub> .HgBr <sub>2</sub>	4400	951	mix.	(1012)
SrBr <sub>2</sub> .2HgBr <sub>2</sub>	8400	1109	mix.	(1012)
2SrBr <sub>2</sub> .HgBr <sub>2</sub>	4800	1744	mix.	(1012)
Sr(CN) <sub>2</sub> .Hg(CN) <sub>2</sub>	600	34	mix.	(1009)
Sr(CN) <sub>2</sub> .2Hg(CN) <sub>2</sub>	900	-231	mix.	(1009)
SrCl <sub>2</sub> .2Hg(CN) <sub>2</sub>	1000	331	mix.	(1009)
SrCl <sub>2</sub> .2Hg(CN) <sub>2</sub> .6H <sub>2</sub> O	c	2115	-66 <sub>100</sub>	(1009)
SrBr <sub>2</sub> .2Hg(CN) <sub>2</sub>	1000	244	mix.	(1009)
SrBr <sub>2</sub> .2Hg(CN) <sub>2</sub> .6H <sub>2</sub> O	c	2039	-78 <sub>100</sub>	(1009)
SrI <sub>2</sub> .2Hg(CN) <sub>2</sub>	1000	134	mix.	(1009)
SrI <sub>2</sub> .2Hg(CN) <sub>2</sub> .7H <sub>2</sub> O	c	2228	-91 <sub>100</sub>	(1009)
Sr(Ag(CN) <sub>2</sub> ) <sub>2</sub>	500	30	Sr(CN) <sub>2</sub> + AgCN	(1011)
SrAg(CN) <sub>2</sub>	600	145	Sr(CN) <sub>2</sub> + AgCN	(1011)
Sr <sub>2</sub> (FeCO(CN) <sub>2</sub> ) <sub>2</sub>	c	1115	167 <sub>100</sub>	(747, 748)
Sr <sub>2</sub> (FeCO(CN) <sub>2</sub> ) <sub>2</sub> .4H <sub>2</sub> O	aq.	1282	N; &	(747, 748)
SrNi(CN) <sub>4</sub>	c	2291	+136 <sub>100</sub>	(747, 748)
3SrCl <sub>2</sub> .4AlCl <sub>3</sub>	220	201	Sr(CN) <sub>2</sub> + Ni(CN) <sub>2</sub>	(1010)
	c	5344	1375.9 <sub>100</sub>	(32)

<b>Barium*</b>				
Ba	c	0	Def.	
Ba <sup>++</sup>	aq.	537	BaCl <sub>2</sub>	
BaO	c	557	150.0 <sub>100</sub> ; &	(87, 404, 976)
BaO <sub>2</sub>	aq.	708	= Ba(OH) <sub>2</sub>	
BaO <sub>2</sub>	c	635	92 <sub>100</sub> HCl; &	(92, 519, 818*)
BaO <sub>2</sub> .H <sub>2</sub> O	c	932	80HCl	(92)
BaO <sub>2</sub> .10H <sub>2</sub> O	c	3576	11.4HCl	(92, 384)
Ba <sub>2</sub> O	c	623	738 <sub>100</sub> HCl (m)	(46)
BaH <sub>2</sub>	c	171	367 <sub>100</sub> HCl; &	(477)
Ba(OH) <sub>2</sub>	c	945.2	47.7 <sub>100</sub>	(67, 404, 976)
	400	993.9	N, BaCl <sub>2</sub> ; &	(9, 67, 476, 940, 976)
Ba(OH) <sub>2</sub> .H <sub>2</sub> O	c	1250	29.5 <sub>100</sub>	(404)
Ba(OH) <sub>2</sub> .8H <sub>2</sub> O	c	3344	-60.7 <sub>100</sub>	(67, 404, 921, 976)
BaO <sub>2</sub> .H <sub>2</sub> O <sub>2</sub>	c	865	49 <sub>100</sub> HCl	(92, 377)
BaF <sub>2</sub>	ppt.	1204	N; &	(464, 793)
	aq.	1192 ?)	-2; &	(793)

\* Ba(NO<sub>3</sub>)<sub>2</sub>.Pb(NO<sub>3</sub>)<sub>2</sub>, solid solutions (889). Ba<sub>2</sub>P<sub>2</sub>O<sub>7</sub> (?) heat of ppt. (888). BaCl<sub>2</sub>.HCl, heat content of HCl (501).

Formula	State	Q, kj	Method	Lit.
<b>Barium.—(Continued)</b>				
BaCl	c	466	236 <sub>100</sub> HCl (m)	(46)
BaCl <sub>2</sub>	c	859.3	8.7 <sub>100</sub>	(32, 52, 157.5, 359, 530, 623, 910, 976)
(see also p. 161, 162)				(652, 627, 920*)
BaCl <sub>2</sub> .2H <sub>2</sub> O	c	1460.9	-20.6 <sub>100</sub>	(52, 260.5, 429, 910, 976)
Ba(ClO) <sub>2</sub>	aq.	757	Cl <sub>2</sub> + Ba(OH) <sub>2</sub>	(59)
Ba(ClO <sub>2</sub> ) <sub>2</sub>	c	660	dissoc.	(252)
Ba(ClO <sub>3</sub> ) <sub>2</sub>	c	728	-28 <sub>100</sub>	(55)
Ba(ClO <sub>3</sub> ) <sub>2</sub> .H <sub>2</sub> O	200	700	+SO <sub>2</sub> ; &	(77, 976)
Ba(ClO <sub>4</sub> ) <sub>2</sub>	c	1033	-47.0 <sub>100</sub>	(55, 976)
Ba(ClO <sub>4</sub> ) <sub>2</sub> .3H <sub>2</sub> O	c	880	-7 <sub>100</sub>	(55, 976)
Ba(ClO <sub>4</sub> ) <sub>2</sub> .3H <sub>2</sub> O	800	872	N; &	(104, 976)
BaCl <sub>2</sub> .BaO.3H <sub>2</sub> O	c	1770	-39 <sub>100</sub>	(55)
BaCl <sub>2</sub> .BaO.5H <sub>2</sub> O	c	2421	+HCl	(11)
BaCl <sub>2</sub> .BaO.8H <sub>2</sub> O	c	3045	77 <sub>100</sub> HCl	(11, 964)
BaBr <sub>2</sub>	c	3899	HCl	(11)
BaBr <sub>2</sub> .2H <sub>2</sub> O	c	755	20.8 <sub>100</sub>	(976, 1009)
Ba(BrO) <sub>2</sub>	400	776	ions	
	c	1366	-17.5 <sub>100</sub>	(976)
BaBr <sub>2</sub> .BaO.2H <sub>2</sub> O	aq.	730	Ba(OH) <sub>2</sub> + Br	(61)
BaBr <sub>2</sub> .BaO.5H <sub>2</sub> O	c	2031	141HBr	(965)
BaI <sub>2</sub>	c	2949	83 <sub>100</sub> HBr	(965)
BaI <sub>2</sub> .7H <sub>2</sub> O	c	606	43.1 <sub>100</sub>	(965)
Ba(IO <sub>3</sub> ) <sub>2</sub>	aq.	649	ions	(965)
	c	2680	-28.7 <sub>100</sub>	(976)
Ba(IO <sub>3</sub> ) <sub>2</sub> .H <sub>2</sub> O	c	1026	-19 <sub>100</sub> K <sub>2</sub> SO <sub>4</sub>	(278)
BaI <sub>2</sub> .BaO.2H <sub>2</sub> O	aq.	990	ions	
BaI <sub>2</sub> .BaO.9H <sub>2</sub> O	c	1324	+Na <sub>2</sub> SO <sub>4</sub>	(278)
BaS	c	1905	139 <sub>100</sub> HI	(965)
BaSO <sub>3</sub>	c	3998	49.2 <sub>100</sub> HI	(965)
BaSO <sub>4</sub>	c	465	114 <sub>100</sub> HCl	(997)
BaSO <sub>4</sub> .H <sub>2</sub> O	aq.	496	N	(60, 976)
BaSO <sub>4</sub> .2H <sub>2</sub> O	ppt.	1170	N	(274)
BaSO <sub>4</sub> .4H <sub>2</sub> O	ppt.	1445	N; &	(55, 748, 976)
BaSO <sub>4</sub> .H <sub>2</sub> SO <sub>4</sub>	aq.	1420	ions; &	(995*)
BaSO <sub>4</sub> .2H <sub>2</sub> SO <sub>4</sub> .H <sub>2</sub> O	aq.	1686	+H <sub>2</sub> SO <sub>4</sub>	(976)
BaI <sub>2</sub> .2SO <sub>3</sub>	c	2287	-29.0 <sub>100</sub>	(976)
BaI <sub>2</sub> .4SO <sub>3</sub>	aq.	1855	+H <sub>2</sub> SO <sub>4</sub>	(135)
BaSe	c	3049	-49 <sub>100</sub>	(135)
BaSeO <sub>4</sub>	aq.	570	N	(976)
BaNa	aq.	1787	N	(374)
Ba <sub>2</sub> N <sub>2</sub>	c	2260	59.6 <sub>100</sub>	(1017)
Ba(NO <sub>3</sub> ) <sub>2</sub>	c	3380	101.0 <sub>100</sub>	(1017)
Ba(NO <sub>3</sub> ) <sub>2</sub> .H <sub>2</sub> O	c	1281	dissoc.*	(342*)
Ba(NO <sub>3</sub> ) <sub>2</sub> .2H <sub>2</sub> O	c	1943	dissoc.*	(342*)
Ba(NO <sub>3</sub> ) <sub>2</sub> .4H <sub>2</sub> O	c	309	142HCl	(369)
Ba(NO <sub>3</sub> ) <sub>2</sub> .6H <sub>2</sub> O	ppt.	1163	BaCl <sub>2</sub> + H <sub>2</sub> SeO <sub>4</sub>	(696)
Ba(NO <sub>3</sub> ) <sub>2</sub> .H <sub>2</sub> O	c	82	-33 <sub>100</sub>	(164)
Ba(NO <sub>3</sub> ) <sub>2</sub> .2H <sub>2</sub> O	aq.	49	+H <sub>2</sub> SO <sub>4</sub>	(164)
Ba(NO <sub>3</sub> ) <sub>2</sub> .4H <sub>2</sub> O	c	380	1498 <sub>100</sub> HCl (m)	(476, 480)
Ba(NO <sub>3</sub> ) <sub>2</sub> .6H <sub>2</sub> O	c	777	-23.8 <sub>100</sub>	(71)
Ba(NO <sub>3</sub> ) <sub>2</sub> .8H <sub>2</sub> O	aq.	753	+H <sub>2</sub> SO <sub>4</sub> ; &	(71)
Ba(NO <sub>3</sub> ) <sub>2</sub> .10H <sub>2</sub> O	c	1075	-26 <sub>100</sub>	(71)
Ba(NO <sub>3</sub> ) <sub>2</sub> .12H <sub>2</sub> O	c	997.2	-39.6 <sub>100</sub>	(55, 924*)
(see also p. 162)	1600	956.0	dil.	(108, 927, 934*)
	800	956.7	N; &	(55, 58, 976)
	400	957.6	dil.	
	200	960.2	dil.	



Formula	State	Q, kj	Method	Lit.
<b>Barium.—(Continued)</b>				
BaNH <sub>3</sub> .....	c	224	446 <sup>8</sup> HCl (300)	(480)
Ba(NH <sub>2</sub> ) <sub>2</sub> .....	c	830	473.3 <sup>8</sup> HCl (300)	(476, 480)
Ba(NH <sub>2</sub> ) <sub>2</sub> .....	c	313	dissoc.*	(191)
BaCl <sub>2</sub> .8NH <sub>3</sub> .....	c	1485	dissoc.*	(531*)
BaBr <sub>2</sub> .NH <sub>3</sub> .....	c	851	dissoc.*	(531*)
BaBr <sub>2</sub> .2NH <sub>3</sub> .....	c	941	dissoc.*	(531*)
BaBr <sub>2</sub> .4NH <sub>3</sub> .....	c	1118	dissoc.*	(531*)
BaBr <sub>2</sub> .8NH <sub>3</sub> .....	c	1468	dissoc.*	(531*)
BaI <sub>2</sub> .2NH <sub>3</sub> .....	c	809	dissoc.*	(531*)
BaI <sub>2</sub> .4NH <sub>3</sub> .....	c	996	dissoc.*	(531*)
BaI <sub>2</sub> .6NH <sub>3</sub> .....	c	1180	dissoc.*	(531*)
BaI <sub>2</sub> .8NH <sub>3</sub> .....	c	1361	dissoc.*	(531*)
BaI <sub>2</sub> .9NH <sub>3</sub> .....	c	1449	dissoc.*	(531*)
BaI <sub>2</sub> .10NH <sub>3</sub> .....	c	1527	dissoc.*	(531*)
Ba <sub>3</sub> (PO <sub>4</sub> ) <sub>2</sub> .....	coll.	408 <sup>6</sup>	N; &	(86, 129)
	c	415 <sup>6</sup>	N	(86, 129)
BaHPO <sub>4</sub> (?).....	ppt.	181 <sup>6</sup>	N	(86, 129, 568)
Ba(H <sub>2</sub> PO <sub>4</sub> ) <sub>2</sub> .....	aq.	1733	+H <sub>2</sub> SO <sub>4</sub>	(976)
Ba(H <sub>2</sub> PO <sub>4</sub> ) <sub>2</sub> .H <sub>2</sub> O.....	c	2018	1.2 <sup>18</sup> <sub>400</sub>	(976)
BaH <sub>4</sub> (PO <sub>4</sub> ) <sub>2</sub> (?).....	ppt.	301 <sup>6</sup>	N	(86)
Ba <sub>3</sub> (AsO <sub>4</sub> ) <sub>2</sub> .....	ppt.	3422	N	(302)
BaHAsO <sub>4</sub> .....	ppt.	1194	N	(976)
BaHAsO <sub>4</sub> .....	ppt.	1435	N	(302)
Ba(H <sub>2</sub> AsO <sub>4</sub> ) <sub>2</sub> .....	ppt.	1961	N	(976)
Ba(H <sub>2</sub> AsO <sub>4</sub> ) <sub>2</sub> .....	ppt.	2334	N	(302)
BaCO <sub>3</sub> .....	ppt.	1217.2	Na <sub>2</sub> CO <sub>3</sub> + BaCl <sub>2</sub>	(55, 58, 568, * 976)
BaCO <sub>3</sub> (II) (witherite).....	c			
BaCO <sub>3</sub> (I).....	c		Tr.; 7.3 <sup>800</sup> <sub>(II)</sub>	(608)
BaCrO <sub>4</sub> .H <sub>2</sub> O.....	ppt.	1663	(NH <sub>4</sub> ) <sub>2</sub> C <sub>2</sub> O <sub>4</sub> + BaCl <sub>2</sub>	(56)
			-10.2 <sup>8</sup> <sub>500</sub>	(53)
Ba(HCO <sub>3</sub> ) <sub>2</sub> .....	c	1376	ions; &	(73)
Ba(C <sub>2</sub> H <sub>3</sub> O <sub>2</sub> ) <sub>2</sub> .....	aq.	1500	22 <sup>11</sup> <sub>600</sub>	(55)
	aq.	1522	+H <sub>2</sub> SO <sub>4</sub>	(53, 55, 976)
Ba(C <sub>2</sub> H <sub>3</sub> O <sub>2</sub> ) <sub>2</sub> .3H <sub>2</sub> O.....	c	2383	-3.4	(55)
Ba(C <sub>2</sub> H <sub>3</sub> O <sub>2</sub> ) <sub>2</sub> .....	c	911	82.7 <sup>19</sup>	(373)
3BaO.4CH <sub>3</sub> OH.....	c	3035	469.3HCl	(380)
3BaO.4C <sub>2</sub> H <sub>5</sub> OH.....	c	3063	205 <sup>16</sup> <sub>3000</sub>	(379)
Ba(C <sub>2</sub> H <sub>3</sub> SO <sub>4</sub> ) <sub>2</sub> .....	aq.	2354	+H <sub>2</sub> SO <sub>4</sub>	(976)
Ba(C <sub>2</sub> H <sub>3</sub> SO <sub>4</sub> ) <sub>2</sub> .2H <sub>2</sub> O.....	c	2905	20.8 <sup>18</sup> <sub>800</sub>	(976)
Ba(CN) <sub>2</sub> .....	c	239	7.4 <sup>9</sup>	(555)
	aq.	247	N; &	(555)
Ba(CN) <sub>2</sub> .H <sub>2</sub> O.....	c	544	-9 <sup>6</sup>	(555)
Ba(CN) <sub>2</sub> .2H <sub>2</sub> O.....	c	838	-20 <sup>7</sup>	(555)
Ba(CNO) <sub>2</sub> .....	c	891	-62 <sup>1000</sup>	(626)
	aq.	829	+HNO <sub>3</sub> ; &	(626)
BaHC <sub>2</sub> N <sub>3</sub> O <sub>3</sub> .1½H <sub>2</sub> O.....	c	1588	96H <sub>2</sub> SO <sub>4</sub>	(626)
Ba(H <sub>2</sub> C <sub>2</sub> N <sub>3</sub> O <sub>3</sub> ) <sub>2</sub> .2H <sub>2</sub> O.....	c	2470	37.3H <sub>2</sub> SO <sub>4</sub>	(626)
Ba(SbOC <sub>2</sub> H <sub>4</sub> O <sub>2</sub> ) <sub>2</sub> .....	c	3512	48HCl; &	(468)
Ba(SbOC <sub>2</sub> H <sub>4</sub> O <sub>2</sub> ) <sub>2</sub> .2H <sub>2</sub> O.....	c	4111	18HCl; &	(468)
BaSiO <sub>3</sub> .....	gla.	1490	BaCO <sub>3</sub> + SiO <sub>2</sub>	(375)
			N; &*	(1090*)
BaSiF <sub>6</sub> .....	c	2835		
BaBr <sub>2</sub> .HgBr <sub>2</sub> .....	4400	945	mix.	(1012)
BaBr <sub>2</sub> .2HgBr <sub>2</sub> .....	8400	1101	mix.	(1012)
2BaBr <sub>2</sub> .HgBr <sub>2</sub> .....	4800	1731	mix.	(1012)
Ba(CN) <sub>2</sub> .Hg(CN) <sub>2</sub> .....	600	27	mix.	(1009)
Ba(CN) <sub>2</sub> .2Hg(CN) <sub>2</sub> .....	900	239	mix.	(1009)
BaCl <sub>2</sub> .2Hg(CN) <sub>2</sub> .....	1000	325	mix.	(1009)
BaCl <sub>2</sub> .2Hg(CN) <sub>2</sub> .5H <sub>2</sub> O.....	c	1827	-72 <sup>18</sup>	(1009)
BaBr <sub>2</sub> .2Hg(CN) <sub>2</sub> .....	1000	237	mix.	(1009)
BaBr <sub>2</sub> .2Hg(CN) <sub>2</sub> .6H <sub>2</sub> O.....	c	2041	-88 <sup>18</sup>	(1009)
BaI <sub>2</sub> .2Hg(CN) <sub>2</sub> .....	900	126	mix.	(1009)
BaI <sub>2</sub> .2Hg(CN) <sub>2</sub> .4H <sub>2</sub> O.....	c	1363	-92 <sup>18</sup>	(1009)
BaAg(CN) <sub>3</sub> .....	1200	136	Ba(CN) <sub>2</sub> + AgCN	(1008)
			Ba(CN) <sub>2</sub> + AgCN	(1008)
Ba(Ag(CN) <sub>3</sub> ) <sub>2</sub> .....	500	20		
BaPtCl <sub>6</sub> .....	c	1192	38 <sup>19</sup> <sub>6000</sub>	(453*)
	aq.	1230	ions*	(453*)
BaPtCl <sub>6</sub> .6H <sub>2</sub> O.....	c	2952	-4.4	(453*)
Ba <sub>2</sub> Fe(CN) <sub>6</sub> .....	aq.	565	N	(555)
Ba <sub>2</sub> Fe(CN) <sub>6</sub> .6H <sub>2</sub> O.....	c	2329	-48 <sup>14</sup>	(555)
BaH <sub>2</sub> Fe(CN) <sub>6</sub> .....	aq.	32	N	(555)
Ba <sub>2</sub> (FeCO(CN) <sub>5</sub> ) <sub>2</sub> .....	c	1186	71 <sup>15</sup> <sub>10000</sub>	(747, 748)
	aq.	1256	N	(747, 748)

Formula	State	Q, kj	Method	Lit.
<b>Barium.—(Continued)</b>				
Ba <sub>2</sub> (FeCO(CN) <sub>5</sub> ) <sub>2</sub> .11H <sub>2</sub> O.....	c	4433	-29 <sup>18</sup> <sub>12000</sub>	(747, 748)
Ba(CN) <sub>2</sub> .Ni(CN) <sub>2</sub> .....	aq.	200	mix.	(1010)
BaCrO <sub>4</sub> .....	ppt.	1398	BaCl <sub>2</sub> + K <sub>2</sub> CrO <sub>4</sub>	(279)
BaCl <sub>2</sub> .2AlCl <sub>3</sub> .....	c	2273	642	(32)
3BaCl <sub>2</sub> .4AlCl <sub>3</sub> .....	c	5404	1295	(32)
<b>Lithium*</b>				
Li.....	c	0	Def.	
Li <sup>+</sup> .....	c	278.1		
Li <sub>2</sub> O.....	c	593	131 <sup>15</sup> <sub>220</sub> ; &	(40, 400*)
4Li <sub>2</sub> O.3H <sub>2</sub> O.....	c	3686	67.1 <sup>15</sup> <sub>250</sub>	(403)
Li <sub>2</sub> O <sub>2</sub> .....	c	627	30.1 <sup>10</sup> ; &	(388)
LiH.....	aq.	657	+HCl	(388)
	c	90	-131 <sup>18</sup> <sub>2000</sub>	(473, 529, * 715)
LiOH.....	c	487	18.7 <sup>24</sup> <sub>110</sub>	(397, 403)
	∞	506.4	dil.	
	2000	506.89	Li + H <sub>2</sub> O; &	(473, 718, * 976, 1074)
	400	506.18	dil.	(400, 401, 567, * 976)
	200	505.97	dil.	
	100	505.71	dil.	
	50	505.41	dil.	
	25	504.9	dil.	
LiOH.H <sub>2</sub> O.....	c	789.2	3.0 <sup>18</sup> <sub>220</sub>	(397, 403)
LiOH.½H <sub>2</sub> O.....	c	536.5	4.3 <sup>15</sup> <sub>25</sub>	(403)
Li <sub>2</sub> O <sub>2</sub> .H <sub>2</sub> O.3H <sub>2</sub> O.....	c	1710	19 <sup>15</sup> <sub>110</sub> ; &	(388)
LiF.....	c	609.1	-4.3 <sup>15</sup> <sub>110</sub>	(410)
	aq.	604.7	N	(793)
LiHF <sub>2</sub> .....	400	920.7	LiF + HF	(793)
LiCl.....	c	407.7	35.6 <sup>18</sup> <sub>200</sub>	(48, 493, 604, 757, 811)
	∞	443.77	dil.	
	400	443.44	dil.	(324, * 604, * 625, 867, * 1003†)
	200	443.27	N	(742, 868, 976)
	100	442.98	dil.	(604)
	50	442.61	dil.	
	25	442.06	dil.	
	10	440.05	dil.	
	5	435.49	dil.	
	3	427.79	dil.	
LiCl.H <sub>2</sub> O.....	c	712.2	17.2	(217, 533*)
LiCl.2H <sub>2</sub> O.....	c	1011.5	4.1	(217, 533*)
LiCl.3H <sub>2</sub> O.....	c	1310.3	dissoc.*	(533*)
LiBr.....	c	350.4	47.1 <sup>14</sup> <sub>850</sub>	(206, 533*)
	200	397.84	N	(868)
LiBr.H <sub>2</sub> O.....	c	665	dissoc.*	(533*)
LiBr.2H <sub>2</sub> O.....	c	969	-5.0; &	(206, 533)
LiBr.3H <sub>2</sub> O.....	c	1270	dissoc.*	(533*)
LiI.....	c	272.0	61.8 <sup>18</sup> <sub>300</sub>	(45, 206)
	200	333.79	N	(533, 568)
LiI.½H <sub>2</sub> O.....	c	435.5	dissoc.*	(533*)
LiI.H <sub>2</sub> O.....	c	595	dissoc.*	(533*)
LiI.2H <sub>2</sub> O.....	c	906	dissoc.*	(533*)
LiI.3H <sub>2</sub> O.....	c	1216	dissoc.*	(533*)
Li <sub>2</sub> SO <sub>4</sub> (I).....	c		Tr.; 2.85 <sup>16</sup> <sub>(II)</sub>	(1001)
Li <sub>2</sub> SO <sub>4</sub> (II).....	c	1414	26.7	(810, 976)
	800	1440	N; &	(976, 1074)
Li <sub>2</sub> SO <sub>4</sub> .H <sub>2</sub> O.....	c	1712	14.3 <sup>18</sup> <sub>400</sub>	(810, * 976)
LiI.SO <sub>2</sub> .....	c	603	dissoc.*	(342*)
LiI.2SO <sub>2</sub> .....	c	932	dissoc.*	(342*)
LiSe.....	c	399	44.6 <sup>10</sup>	(350)
	aq.	444	N	(350)
Li <sub>2</sub> Se.9H <sub>2</sub> O.....	c	3070	-51 <sup>1000</sup>	(350)
Li <sub>3</sub> N.....	c	192	549	(474)
LiNO <sub>2</sub> .....	c	484.7	1.8 <sup>21</sup> <sub>400</sub>	(493, 811, 976)
	∞	486.59	dil.	(867*)
	400	486.46	dil.	

\* LiCl + HCl, partial heat content of HCl (500).



Formula	State	Q, kj	Method	Lit.
<b>Lithium.—(Continued)</b>				
LiNO <sub>2</sub> —(Continued)	200	486.36	N	(868°)
	100	486.25	dil.	
	50	486.15	dil.	
	25	486.05	dil.	
	3	481.3	analogy	
LiNO <sub>2</sub> ·3H <sub>2</sub> O	c	1374.0	→liq.	(731)
LiNH <sub>2</sub>	c	179	232 <sup>15</sup> <sub>HCl(200)</sub>	(480)
Li(NH <sub>2</sub> ) <sub>2</sub>	liq.	328	dissoc.*	(46*)
Li <sub>2</sub> NH	c	217	472 <sup>15</sup> <sub>HCl</sub>	(480)
LiCl·NH <sub>3</sub>	c	502.3	22.4 <sup>15</sup> <sub>380</sub> ; &	(187,* 220*)
LiCl·2NH <sub>3</sub>	c	594.8	11.2 <sup>18</sup> <sub>440</sub> ; &	(187,* 220*)
LiCl·3NH <sub>3</sub>	c	685.8	1.5 <sup>18</sup> <sub>550</sub> ; &	(187,* 220*)
LiCl·4NH <sub>3</sub>	c	767.6	1.0 <sup>11</sup> <sub>660</sub> ; &	(187,* 220*)
LiCl·5NH <sub>3</sub>	c	846	dissoc.*	(187)
LiBr·NH <sub>3</sub>	c	450	28.7 <sup>15</sup> <sub>330</sub> ; &	(187, 220*)
LiBr·2NH <sub>3</sub>	c	548	12.6 <sup>8</sup> <sub>440</sub> ; &	(187, 220*)
LiBr·3NH <sub>3</sub>	c	640	1.2 <sup>10</sup> <sub>550</sub> ; &	(187, 220*)
LiBr·4NH <sub>3</sub>	c	729	-6.5 <sup>8</sup> <sub>600</sub> ; &	(187, 220*)
LiBr·5NH <sub>3</sub>	c	809	dissoc.*	(187*)
LiBr·6½NH <sub>3</sub>	c	921	dissoc.*	(187*)
LiI·NH <sub>3</sub>	c	385	dissoc.*	(187*)
LiI·2NH <sub>3</sub>	c	489	dissoc.*	(187*)
LiI·3NH <sub>3</sub>	c	585	dissoc.*	(187*)
LiI·4NH <sub>3</sub>	c	680	dissoc.*	(187*)
LiI·5NH <sub>3</sub>	c	759	dissoc.*	(187*)
LiI·5½NH <sub>3</sub>	c	797	dissoc.*	(187*)
LiI·7NH <sub>3</sub>	c	910	dissoc.*	(187*)
Li <sub>2</sub> C <sub>2</sub>	c	57	155 <sup>17</sup>	(475)
Li <sub>2</sub> CO <sub>3</sub>	c	1217	12.8 <sup>15</sup> <sub>220</sub>	(402, 568*)
	aq.	1230	N; &	(402, 742)
LiHCO <sub>3</sub>	500	972	+HCl aq.	(742)
LiCH <sub>2</sub> O(CH <sub>2</sub> OH)	CH <sub>2</sub> OH	482	Li + CH <sub>2</sub> OH	(376)
LiC <sub>2</sub> H <sub>3</sub> O(C <sub>2</sub> H <sub>5</sub> OH)	C <sub>2</sub> H <sub>5</sub> OH	491	Li + C <sub>2</sub> H <sub>5</sub> OH	(376)
LiCN	200	131	N	(1007)
LiCl·CH <sub>3</sub> NH <sub>2</sub>	c	496	27.9 <sup>200</sup>	(221)
LiCl·2CH <sub>3</sub> NH <sub>2</sub>	c	577	28.0 <sup>200</sup>	(221)
LiCl·3CH <sub>3</sub> NH <sub>2</sub>	c	653	33.0 <sup>200</sup>	(221)
Li <sub>2</sub> SiO <sub>3</sub>	gls.	1560	Li <sub>2</sub> CO <sub>3</sub> + SiO <sub>2</sub>	(278)
	c	1820	gls.	(917)
Li <sub>2</sub> SiF <sub>6</sub>	c	2835.3	7.6 <sup>200</sup>	(1001)
	aq.	2842.9	LiF + SiF <sub>4</sub>	(1001)
LiCl·ThCl <sub>4</sub>	c	1822	262.2	(268)
LiCl·ThCl <sub>4</sub> ·8H <sub>2</sub> O	c	4269	105.1	(268)
2LiCl·ThCl <sub>4</sub>	c	2239	288.0	(268)
LiHg	c	84	Li + Hg	(1074)
LiHg <sub>2</sub>	c	94	+H <sub>2</sub> SO <sub>4</sub>	(1074)
LiHg <sub>3</sub>	c	105	+H <sub>2</sub> SO <sub>4</sub>	(1074)
LiHg <sub>4</sub>	liq.	82.0	Li + Hg*	(639*)
LiBr·HgBr <sub>2</sub>	4200	559	mix.	(1012)
2LiBr·HgBr <sub>2</sub>	4400	962	mix.	(1012)
4LiBr·HgBr <sub>2</sub>	4800	1765	mix.	(1012)
LiCN·Hg(CN) <sub>2</sub>	400	-112	mix.	(1009)
2LiCN·Hg(CN) <sub>2</sub>	600	41	mix.	(1009)
LiCl·Hg(CN) <sub>2</sub>	1000	172	mix.	(1009)
LiBr·Hg(CN) <sub>2</sub>	1000	128	mix.	(1009)
LiBr·Hg(CN) <sub>2</sub> ·3H <sub>2</sub> O	c	1168	-38.3 <sup>15</sup>	(1009)
LiI·Hg(CN) <sub>2</sub>	1000	73	mix.	(1009)
LiI·Hg(CN) <sub>2</sub> ·3H <sub>2</sub> O	c	1118	-43.3 <sup>15</sup>	(1009)
<b>Sodium</b>				
Na	c	0	Def.	
	gas	-105	→c*	(438,* 489,* 491,* 876*)

\* Heats of solution of melted salt mixtures:

	Fresh fused	Old fused	Lit.
Na <sub>2</sub> SO <sub>4</sub> ·MgSO <sub>4</sub>	71.6 <sup>17</sup>	69.8 <sup>19</sup>	(187.5)
2NaCl·CaCl <sub>2</sub>	62.4 <sup>19</sup>	62.9 <sup>14</sup>	
2NaCl·SrCl <sub>2</sub>	36.9 <sup>13</sup>	35.3 <sup>14</sup>	
Na <sub>2</sub> SO <sub>4</sub> ·SrSO <sub>4</sub>	2.8	5.4 <sup>18</sup>	
2NaCl·BaCl <sub>2</sub>	-3.9	3.4	
Na <sub>2</sub> SO <sub>4</sub> ·BaSO <sub>4</sub>	8.2 <sup>14</sup>	8.7 <sup>17</sup>	
2Na <sub>2</sub> SO <sub>4</sub> ·BaSO <sub>4</sub>	11.2 <sup>18</sup>	5.4 <sup>18</sup>	(777)
NaCl·LiI	-44.4 <sup>200</sup>		(48)

NaCl + HCl, partial heat content HCl (°00).

2NaCl·BaCl<sub>2</sub>, heat of dilution (°30).

Formula	State	Q, kj	Method	Lit.
<b>Sodium.—(Continued)</b>				
Na <sup>+</sup>	∞	240.8	NaCl; &	(39, 40, 283, 884°)
Na <sub>2</sub> O	c	415	236	(383)
Na <sub>2</sub> O <sub>2</sub>	c	495.6	175.0HCl; &	(383)
Na <sub>2</sub> O (?)	c	425	409	(383)
NaH	c	55	109 <sup>18</sup> <sub>200</sub> ; &	(294, 579,* 736,* 956)
NaOH(β)	c	428.5	43.1 <sup>32</sup> <sub>160</sub>	(85,* 292, 976)
NaOH(α)	c		Tr.; 4.1 <sup>299.6</sup> <sub>(β)</sub>	(815)
(see also p. 161)	∞	468.88	dil.	(68, 408, 827,* 867,* 897, 976,* 1003†)
	500	468.90	dil.	
	400	468.92	dil.	
	200	468.98	dil.	
	100	469.14	Na + H <sub>2</sub> O	(6, 289, 888, 884, 976)
	50	469.48	dil.	
	25	469.54	dil.	
	13.5	470.23	dil.	
	9	469.5	dil.	
	7	469.1	dil.	
	5	465.5	dil.	
	3	456.6	dil.	
NaOH·½H <sub>2</sub> O	c	577	35 <sup>13</sup> <sub>160</sub>	(292)
NaOH·H <sub>2</sub> O	c	725	30.1 <sup>22</sup> <sub>180</sub>	(68, 292)
NaHO <sub>2</sub>	aq.	393	+HNO <sub>3</sub> ; &	(574)
NaF	c	570.4	-2 <sup>13</sup> <sub>400</sub>	(464)
	aq.	567.9	N; &	(740, 976)
NaHF <sub>2</sub>	c	909	-26 <sup>12</sup> <sub>400</sub>	(464)
	400	883	NaF + HF	(976)
NaCl	c	411.64	-5.36 <sup>18</sup> <sub>200</sub>	(46, 84, 187.5,* 241,† 298,* 623,* 777, 837,* 909,* 934, 976, 1006,*† 1040°)
	gas	184	→(c)	(366, 492)
	∞	406.28	dil.	(6,*† 22, 622, 853, 827,* 837,*† 867,* 909, 934,† 938,*† 976, 1076°)
	500	406.26	dil.	
	400	406.26	dil.	
	200	406.30	N; &	(6,* 50, 187, 230, 580,* 640,* 670, 671, 742,* 867,* 940, 976,* 1006°)
	100	406.50	dil.	
	50	406.99	dil.	
	25	407.86	dil.	
	10	409.2	dil.	
NaClO	800	349	N; &	(976)
NaClO <sub>2</sub>	c	344.6	+KNO <sub>3</sub> ; &	(58, 246°)
	aq.	322.5	N; &	(976)
NaClO <sub>4</sub>	c	421	-15 <sup>10</sup> <sub>400</sub>	(52, 55)
	aq.	407	ions	(104)
NaBr	c	361.3	-0.8 <sup>18</sup> <sub>200</sub>	(55, 260.5, 976)
	200	360.54	N; &	(867°)
	100	361.0	dil.	(313,† 324†)
	14	363.3	dil.	
	6.8	365.1	dil.	
NaBr·2H <sub>2</sub> O	c	953	-19.7 <sup>18</sup> <sub>200</sub>	(55, 260.5, 976)
NaBrO	aq.	331	NaOH + Br	(81, 976)
NaI	c	290.7	5.9 <sup>18</sup> <sub>200</sub>	(55, 260.5, 811, 976, 1009)
	200	296.59	N	(868°)
NaI·2H <sub>2</sub> O	c	885.7	-16.8 <sup>18</sup> <sub>200</sub>	(55, 260.5, 976)
Na <sub>2</sub> S	c	376	65; &	(858, 897)
	400	440.3	N; &	(50, 60, 897, 976)
	200	440.4	dil.	(897)
	100	440.8	dil.	
	50	441.2	dil.	
	20	442.3	dil.	
	10	443.7	dil.	



Formula	State	Q, kj	Method	Lit.
<b>Sodium.—(Continued)</b>				
$\text{Na}_2\text{S}_4\cdot 4\text{H}_2\text{O}$	c	1749	$-21^{17}_{1000}$	(897)
$\text{Na}_2\text{S}_5\cdot 5\text{H}_2\text{O}$	c	1899	$-28^{13}_{1000}$	(897)
$\text{Na}_2\text{S}_9\cdot 9\text{H}_2\text{O}$	c	3086	$-70^{13}_{1000}$	(897)
$\text{Na}_2\text{S}_2$	aq.	442	+HI	(897)
$\text{Na}_2\text{S}_3$	aq.	449	+HI	(897)
$\text{Na}_2\text{S}_4$	c	414	$41^{17}_{1200}$	(897)
	aq.	455	+HI	(897)
$\text{Na}_2\text{SO}_3$	c	1085	$10^{10}$	(375)
	800	1096	N	(375, 646, <sup>o</sup> 976)
$\text{Na}_2\text{SO}_3\cdot 7\text{H}_2\text{O}$	c	3145	$-46^{10}_{600}$	(375)
$\text{Na}_2\text{SO}_4$	c	1365.6	$2.3^{18}_{400}$	(53, 157.5, <sup>o</sup> 246,* 380.5, 458, 707, 804, <sup>o</sup> 807, 891, 976, 979, 1006 <sup>o</sup> )
	$\infty$	1367.1	extrap.	
	800	1367.5	dil.	
	400	1367.9	N; &	(50, 53, 671, 745, 843, 976 <sup>o</sup> )
	200	1369.0	dil.	(976, <sup>o</sup> 1006 <sup>o</sup> )
	100	1370.9	dil.	
	50	1373.7	dil.	
$\text{Na}_2\text{SO}_4\cdot 10\text{H}_2\text{O}$	c	4309.0	$-79.1^{18}_{400}$	(281, 355, 360.5, 458, 807, <sup>o</sup> 976, 978, <sup>o</sup> 979, 1100)
$\text{Na}_2\text{S}_2\text{O}_3$	c	1064	$7^{15}_{440}$	(117, 369)
	aq.	1071	+HClO	(132, 976)
$\text{Na}_2\text{S}_2\text{O}_3\cdot 5\text{H}_2\text{O}$ (a)	c	2550	$-47.6^{18}_{400}$	(121, 976)
$\text{Na}_2\text{S}_2\text{O}_3\cdot 5\text{H}_2\text{O}$ (p)	c	2546.1	Tr.; $3.87^{18}_{(a)}$	(737 <sup>o</sup> )
$\text{Na}_2\text{S}_2\text{O}_4$	aq.	1146	+O <sub>2</sub>	(78)
$\text{Na}_2\text{S}_2\text{O}_5$	c	1452	$-22^{10}_{600}$	(375)
	1200	1430	N	(375, 976)
$\text{Na}_2\text{S}_2\text{O}_6$	c	1653	$-23.8^{19}_{400}$	(976)
	400	1629	ions	(976)
$\text{Na}_2\text{S}_2\text{O}_8\cdot 2\text{H}_2\text{O}$	c	2250	$-48.8^{17}_{400}$	(976)
$\text{Na}_2\text{S}_2\text{O}_8$	aq.	1575	+Br <sub>2</sub> ; &	(131)
$\text{Na}_2\text{S}_2\text{O}_8\cdot 3\text{H}_2\text{O}$	c	2475	$-42^{11}_{1000}$	(131)
$\text{Na}_2\text{S}_4\text{O}_6$	aq.	1578	$\text{Na}_2\text{S}_2\text{O}_3$ + I; &	(131, 976)
$\text{Na}_2\text{S}_4\text{O}_6\cdot 2\text{H}_2\text{O}$	c	2191	$-41^{10}_{600}$	(131)
$\text{NaHS}_2$	c	239	$18^{16}_{600}$	(897)
	400	257.2	dil.	
	200	257.3	N; &	(897, 976)
	100	257.6	dil.	(897)
	50	258.0	dil.	
	20	259.7	dil.	
	10	265.7	dil.	
$\text{NaHS}\cdot 2\text{H}_2\text{O}$	c	836	$-6.4^{18}_{400}$	(897)
$\text{NaHSO}_3$	600	858	$-\text{Na}_2\text{S}_2\text{O}_3$	
$\text{NaHSO}_4$	c	1109.8	$5.0^{17}_{200}$	(50, 976)
	800	1116.8	dil.	(976)
	400	1115.9	dil.	
	200	1114.8	N; &	(843, 976)
	100	1114.2	dil.	
	50	1114.0	dil.	
	20	1113.6	dil.	
	10	1111.8	dil.	
$\text{NaHSO}_4\cdot \text{H}_2\text{O}$	c	1402	-1.2	(355)
$\text{NaI}\cdot 28\text{O}_2$	c	955	dissoc.*	(343,* 425*)
$\text{NaI}\cdot 48\text{O}_2$	c	1615	dissoc.*	(342,* 425*)
$\text{Na}_2\text{Se}$	c	291	$77.8^{14}_{200}$	(350)
	aq.	369	N	(350)
$\text{Na}_2\text{Se}_4\cdot 4\text{H}_2\text{O}$	c	1690	-33	(350)
$\text{Na}_2\text{Se}_9\cdot 9\text{H}_2\text{O}$	c	2989	-44	(350)
$\text{Na}_2\text{Se}_{16}\cdot 16\text{H}_2\text{O}$	c	4980	$-92^{14}_{3000}$	(350)
$\text{Na}_2\text{SeO}_3$	800	997	N	(976)
$\text{Na}_2\text{SeO}_4$	c	1094	Se + $\text{Na}_2\text{O}_2$	(711)
	400	1094	N; &	(696, 976)
$\text{NaHSe}$	aq.	187	N	(350)

Formula	State	Q, kj	Method	Lit.
<b>Sodium.—(Continued)</b>				
$\text{NaHSeO}_3$	600	763	N	(976)
$\text{NaHSeO}_4$	aq.	844.7	$\text{Na}_2\text{SeO}_4$ + $\text{H}_2\text{SeO}_4$ ; &	(696, 976)
$\text{Na}_2\text{TeO}_4$	c	1283	Te + $\text{Na}_2\text{O}_2$	(711)
	aq.	1205	N	(696)
$\text{NaNO}_2$	c	362	-14.7 <sup>100</sup>	(686, 954)
	aq.	348	+HCl + $\text{CO}(\text{NH}_2)_2$	(686, 954)
$\text{NaNO}_3$	c	470.6	-21.0 <sup>17}_{200}</sup>	(53, 246,* 492, 909, 924, <sup>†</sup> 976, 978, <sup>o</sup> 1006, <sup>o</sup> 1046 <sup>o</sup> )
(see also p. 162)	$\infty$	449.18	dil.	
	400	449.32	dil.	
	200	449.66	N	(52, 671, 867,* 976)
	100	450.34	dil.	(198, 312, <sup>†</sup> 827, <sup>o</sup> 867, 890, <sup>†</sup> 934, <sup>†</sup> 938)
	50	451.44	dil.	
	25	453.27	dil.	
	6	458.0	dil.	
$\text{Na}_2(\text{NO})_2$	aq.	466	$\text{Sr}(\text{NO})_2\cdot 5\text{H}_2\text{O}$ + $\text{Na}_2\text{SO}_4$ ; &	(132)
$\text{NaNH}_2$	c	135	$130^{31}$	(382)
$\text{NaNH}_3$	c	67.6	dissoc.	(559)
$\text{NaCl}\cdot 5\text{NH}_3$	c	808	dissoc.*	(187*)
$\text{NaBr}\cdot 5\frac{1}{2}\text{NH}_3$	c	1045	dissoc.*	(187*)
$\text{NaI}\cdot 4\frac{1}{2}\text{NH}_3$	c	674	dissoc.*	(187*)
$\text{NaI}\cdot 6\text{NH}_3$	c	790	dissoc.*	(187*)
$\text{Na}_2\text{SO}_4\cdot (\text{NH}_4)_2\text{SO}_4\cdot \text{H}_2\text{O}$	c	3719	-54.4 <sup>16</sup>	(688)
$\text{NaPO}_3$	c	1209	$16.6^{15}$	(447)
	600	1225	N	(447)
$\text{Na}_3\text{PO}_4$ (?)	c	1871	P + $\text{Na}_2\text{O}_2$	(710)
$\text{Na}_3\text{PO}_4$	900	1972.4	N	(160, 161, 976)
$\text{Na}_3\text{PO}_4\cdot 12\text{H}_2\text{O}$	c	5467	-61 <sup>18}_{600}</sup>	(569)
$\text{Na}_4\text{P}_2\text{O}_7$	aq.	1042 + $\text{H}_4\text{P}_2\text{O}_7$	N	(567)
$\text{Na}_4\text{P}_2\text{O}_7$	c	3160	$49.6^{18}_{800}$	(976)
	1600	3210	N	(447, 976)
$\text{Na}_4\text{P}_2\text{O}_7\cdot 10\text{H}_2\text{O}$	c	6120	-48.8 <sup>18}_{800}</sup>	(976)
$\text{NaH}_2\text{PO}_2$	aq.	837	N	(976)
$\text{NaH}_2\text{PO}_3$	c	1199	$3.1^{15}_{600}$	(8)
	600	1202	N	(8, 976)
$\text{NaH}_2\text{PO}_3\cdot 2\frac{1}{2}\text{H}_2\text{O}$	c	1940	-22 <sup>15}_{600}</sup>	(8)
	300	1525.9	N	(160, 161, 976)
$\text{NaH}_2\text{P}_2\text{O}_6$	aq.	246 + $\text{H}_4\text{P}_2\text{O}_6$	N	(567)
$\text{NaH}_2\text{P}_2\text{O}_7$	c	2498	$2.8^{15}$	(447)
	1200	2501	N; &	(447, 976)
$\text{NaH}_2\text{PO}_4\cdot \text{H}_3\text{PO}_4$	c	2803	$4.7^{15}$	(446, 447)
$\text{Na}_2\text{HPO}_3$	c	1403.8	$38.3^{14}_{600}$	(8)
	aq.	1442	N	(8)
$\text{Na}_2\text{HPO}_3\cdot 5\text{H}_2\text{O}$	c	2892	-19.2 <sup>15}_{600}</sup>	(8)
$\text{Na}_2\text{HPO}_4$	c	1736.7	$23.6^{18}_{400}$	(801, 802, 976)
	600	1760.3	N	(160, 161, 976)
$\text{Na}_2\text{HPO}_4\cdot 2\text{H}_2\text{O}$	c	2334.3	-1.6 <sup>18}_{400}</sup>	(976)
$\text{Na}_2\text{HPO}_4\cdot 7\text{H}_2\text{O}$	c	3812	-48 <sup>18}_{400}; &amp;</sup>	(430,* 749,* 801, 802, 976)
$\text{Na}_2\text{HPO}_4\cdot 12\text{H}_2\text{O}$	c	5289.9	-95.5 <sup>18}_{400}</sup>	(216, 749, 801, 802, 976)
$\text{Na}_2\text{H}_2\text{P}_2\text{O}_5$	c	2088	$1^{15}_{1100}$	(2)
	aq.	2090	N	(8, 359)
$\text{Na}_2\text{H}_2\text{P}_2\text{O}_6$	aq.	492 + $\text{H}_4\text{P}_2\text{O}_6$	N	(567)
$\text{Na}_2\text{H}_2\text{P}_2\text{O}_7$	c	2753	-9.5	(447)
	1200	2744	N	(447, 976)
$\text{Na}_2\text{H}_2\text{P}_2\text{O}_7\cdot 6\text{H}_2\text{O}$	c	4519	-58.2	(447)
$\text{Na}_2\text{HP}_2\text{O}_6$	aq.	728 + $\text{H}_4\text{P}_2\text{O}_6$	N	(567)
$\text{Na}_2\text{HP}_2\text{O}_7$	c	2954	28.3	(447)



Formula	State	Q, kj	Method	Lit.
<b>Sodium.—(Continued)</b>				
$\text{Na}_2\text{HP}_2\text{O}_7$ —(Cont'd)	aq.	2982	N	(447)
$\text{Na}_2\text{HP}_2\text{O}_7 \cdot \text{H}_2\text{O}$	c	3264	4.7	(447)
$\text{Na}_2\text{HP}_2\text{O}_7 \cdot 6\text{H}_2\text{O}$	c	4729	-29.6	(447)
$\text{NaNH}_4\text{HPO}_4$	aq.	1652	N	(129, 160)
$\text{NaNH}_4\text{HPO}_4 \cdot 4\text{H}_2\text{O}$	c	2842	-45.0 <sup>18</sup> <sub>800</sub>	(976)
$\text{Na}_2\text{AsO}_4$	c	1500 (?)	As + $\text{Na}_2\text{O}_2$	(710)
	500	1597	N	(976)
$\text{Na}_2\text{AsO}_4 \cdot 12\text{H}_2\text{O}$	c	5084	-53 <sup>18</sup> <sub>600</sub>	(569)
$\text{NaH}_2\text{AsO}_4$	400	952	N	(976)
$\text{NaH}_2\text{AsO}_4$	300	1143	N	(976)
$\text{Na}_2\text{HAsO}_4$	400	1137	N	(976)
$\text{Na}_2\text{HAsO}_4$	400	1377	N	(976)
$\text{Na}_2\text{SbO}_4$	c	1653	Sb + $\text{Na}_2\text{O}_2$	(710)
	aq.	1605	N; analogy	
$3\text{Na}_2\text{S} \cdot \text{Sb}_2\text{S}_3$	1200	1561	+HCl; &	(127, 148, 463)
$\text{Na}_2\text{BiO}_4$ (?)	c	1181	Bi + $\text{Na}_2\text{O}_2$	(710)
$\text{Na}_2\text{C}_2$	c	-20	272HCl; &	(381, 673)
$\text{Na}_2\text{CO}_3$	c	1132.3	23.6 <sup>18</sup> <sub>400</sub> ; &	(112, 361, 706, 777, 810, 976, 978)
	400	1155.8	N; &	(50, 742, 976)
	200	1157.1	dil.	(601, † 976)
	100	1158.9	dil.	
	50	1161.6	dil.	
	30	1164.0	dil.	
$\text{Na}_2\text{CO}_3 \cdot \text{H}_2\text{O}$	c	1432.6	9.4 <sup>18</sup> <sub>400</sub>	(320, † 976)
$\text{Na}_2\text{CO}_3 \cdot 7\text{H}_2\text{O}$	c	3204.2	-45 <sup>18</sup> <sub>400</sub>	(320, † 976)
$\text{Na}_2\text{CO}_3 \cdot 10\text{H}_2\text{O}$	c	4085.2	-67.6 <sup>18</sup> <sub>400</sub>	(52, 360.5, 810, 976, 978)
$\text{Na}_2\text{CrO}_4$	c	1322.5	-23 <sup>18</sup> <sub>100</sub>	(56)
	450	1299.2	N	(52, 976)
$\text{NaHC}_2$	c	-105	61; &	(673)
$\text{NaCHO}_2$	c	657.1	-2.2 <sup>12</sup> <sub>160</sub>	(55)
	400	654.9	N	(73, 976)
$\text{NaHCO}_3$	c	952	-18 <sup>18</sup> ; &	(56, 263*)
	200	934.7	N	(50, 56, 976)
$\text{NaHCO}_3 \cdot \text{H}_2\text{O}$	c	1064	dissoc.*	(263*)
$\text{NaCH}_2\text{O}$	$\text{CH}_3\text{OH}$	452	Na + $\text{CH}_2\text{OH}$	(376)
$\text{NaHC}_2\text{O}_4$	c	1079	-23 <sup>18</sup> <sub>100</sub>	(53)
	400	1056	N	(52, 976)
$\text{NaHC}_2\text{O}_4 \cdot \text{H}_2\text{O}$	c	1382	-40 <sup>18</sup> <sub>100</sub>	(52, 976)
$\text{NaC}_2\text{H}_3\text{O}_3$	c	716.3	16.5 <sup>18</sup> <sub>200</sub>	(55, 810, 976)
	400	732.8	N; &	(72, 114, 671, 976)
	100	732.7	dil.	(51, 976)
	50	732.5	dil.	
	25	732.1	dil.	
	10	730.7	dil.	
	3	730	→ $\text{NaC}_2\text{H}_3\text{O}_3 \cdot 3\text{H}_2\text{O}$	(455)
$\text{NaC}_2\text{H}_3\text{O}_3 \cdot 3\text{H}_2\text{O}$	c	1610	-19.2 <sup>18</sup> <sub>100</sub>	(52)
$\text{NaC}_2\text{H}_3\text{O}_3$	$\text{C}_2\text{H}_5\text{OH}$	463	Na + $\text{C}_2\text{H}_5\text{OH}$	(376)
	c	413	56.4 <sup>10</sup>	(372)
$\text{NaHC}_2\text{H}_4\text{O}_3$	c	1509	-23.7	(56, 134)
	aq.	1486	N	(56, 134)
$\text{NaHC}_2\text{H}_4\text{O}_3 \cdot \text{H}_2\text{O}$	c	1807	-35.7	(56, 134)
$\text{NaC}_2\text{H}_3\text{O}_3 \cdot \text{HC}_2\text{H}_3\text{O}_3$	c	1219	8 <sup>18</sup> <sub>100</sub>	(56)
$\text{NaC}_2\text{H}_3\text{O}_3 \cdot 2\text{HC}_2\text{H}_3\text{O}_3$	c	1740	-20	(52)
$\text{NaC}_2\text{H}_3\text{O}_3 \cdot 2\text{C}_2\text{H}_5\text{OH}$	c	998	43.8	(372)
$\text{NaC}_2\text{H}_3\text{O}_3 \cdot 3\text{C}_2\text{H}_5\text{OH}$	c	1276	51.4	(372)
$\text{Na}_2\text{C}_4\text{H}_4\text{O}_6$	c	1725	-4.7	(56, 134)
	aq.	1721	N	(56, 134)
$\text{Na}_2\text{C}_4\text{H}_4\text{O}_6 \cdot 2\text{H}_2\text{O}$	c	2318	-24.6	(56, 134)
$\text{NaC}_2\text{H}_3\text{SO}_4$	aq.	1145	$\text{Ba}(\text{C}_2\text{H}_3\text{SO}_4)_2$ + $\text{Na}_2\text{SO}_4$	(976)
			-2.1 <sup>9</sup> <sub>100</sub>	(555)
$\text{NaCN}$	c	96	N	(976)
	200	94	-4.2 <sup>5</sup> <sub>110</sub>	(555)
$\text{NaCN} \cdot \frac{1}{2}\text{H}_2\text{O}$	c	241	-18.5 <sup>4</sup> <sub>100</sub>	(555)
$\text{NaCN} \cdot 2\text{H}_2\text{O}$	c	685	-20.1 <sup>13</sup> <sub>2000</sub>	(626)
$\text{NaCNO}$	c	406	+HCl	(626)
	aq.	386	6.1 <sup>121</sup> <sub>1500</sub>	(626)
$\text{Na}_2\text{C}_2\text{N}_2\text{O}_2$	c	1274	N	(626)
	aq.	1260	N	(626)
$\text{NaCN}_2\text{H}$	aq.	146	N	(626)
$\text{NaH}_2\text{C}_2\text{N}_2\text{O}_2$	c	911	-20.5 <sup>2000</sup>	(626)

Formula	State	Q, kj	Method	Lit.
<b>Sodium.—(Continued)</b>				
$\text{NaH}_2\text{C}_2\text{N}_2\text{O}_2$ —(Cont'd)	aq.	890	N	(626)
$\text{NaH}_2\text{C}_2\text{N}_2\text{O}_2 \cdot \text{H}_2\text{O}$	c	1214	-37.1 <sup>18</sup> <sub>2000</sub>	(626)
$\text{Na}_2\text{HC}_2\text{N}_2\text{O}_2$	c	1098	-7.4 <sup>20</sup> <sub>1500</sub>	(626)
$\text{NaCNS}$	aq.	1091	N	(626)
	c	179	-13.9 <sup>18</sup> <sub>100</sub>	(1023)
$\text{Na}_2\text{SiO}_2$	aq.	165	N	(555)
	gl.	1545	$\text{SiO}_2$ + $\text{Na}_2\text{O}_2$	(275, 706)
$\text{Na}_2\text{SiF}_6$	c	1544	234.1HF	(682, 749)
	c	2766	N	(1001, 1090*)
	aq.	2755	N; &	(976, 1001, 1090*)
$\text{Na}_2\text{O}_2 \cdot \text{TiO}_2$ (from Ti + $\text{Na}_2\text{O}_2$ )	c	2102	Ti + $\text{Na}_2\text{O}_2$	(706)
$\text{Na}_2\text{TiF}_6$	aq.	2808	N = $\text{H}_2\text{SiF}_6$	(189)
$\text{NaSn}$	c	46	485HCl(a) +	(189)
			$\text{FeCl}_3$	
$\text{NaSn}_2$	c	63	741HCl(a) +	(189)
			$\text{FeCl}_3$	
$\text{Na}_2\text{Sn}$	c	50	741HCl(a) +	(189)
			$\text{FeCl}_3$	
$\text{Na}_4\text{Sn}$	c	88	1218HCl(a) +	(189)
			$\text{FeCl}_3$	
$\text{Na}_6\text{Sn}_3$	c	151	1695HCl(a) +	(189)
			$\text{FeCl}_3$	
$\text{Na}_2\text{SnO}_2$	aq.	937.3	$\text{HSnCl}_3$ +	(976)
			$\text{NaOH}$	
$\text{Na}_2\text{SnO}_4$ (?)	c	1549	Sn + $\text{Na}_2\text{O}_2$	(706)
	aq.	1897	$\text{SnCl}_4$ +	(976)
			$\text{NaOH}$	
$\text{NaPbO}_2$	c	842	$\text{Na}_2\text{O}_2$ + Pb	(706)
$2\text{Na}_2\text{S}_2\text{O}_3 \cdot \text{PbS}_2\text{O}_3$	c	2770	-17	(369)
	aq.	2753	mix.	(369)
$\text{NaCl} \cdot \text{ThCl}_4 \cdot 10\text{H}_2\text{O}$	c	4933	-24.0	(268)
$2\text{NaCl} \cdot \text{ThCl}_4$	c	2244	209.4	(268)
$\text{Na}_2\text{ZnO}_2$	c	778	$\text{Na}_2\text{O}_2$ + Zn	(712)
$\text{Na}_2\text{Zn}(\text{SO}_4)_2$	c	2364	+41	(489)
	aq.	2406	mix.	(489)
$\text{Na}_2\text{Zn}(\text{SO}_4)_2 \cdot 4\text{H}_2\text{O}$	c	3551	-0.7	(489)
$\text{NaCd}_2$	c	36	+Br	(187)
$\text{NaCd}_2$	c	52	+Br	(187)
$\text{Na}_2\text{CdO}_2$ (?)	c	681	Cd + $\text{Na}_2\text{O}_2$	(715)
$\text{NaHg}_2$	c	46	195HCl	(89)
$\text{NaHg}_4$	c	78	163HCl	(89)
$\text{Na}_2\text{Hg}$	c	53.8	199.3Hg	(1030)
$\text{NaHg}_{27.5}$	liq.	82.01	dil.	(256, † 889†)
$\text{NaHg}_{59.0}$	liq.	82.82	dil.	(256, † 889†)
$\text{NaHg}_{116}$	liq.	83.11	Na + Hg	(646, † 1030)
$\text{NaHg}_{230}$	liq.	83.29	dil.	(256, † 889†)
$\text{NaHg}_{460}$	liq.	83.41	dil.	(256, † 889†)
$\text{NaBr} \cdot \text{HgBr}_2$	4200	522	mix.	(1012)
$2\text{NaBr} \cdot \text{HgBr}_2$	4400	887	mix.	(1012)
$4\text{NaBr} \cdot \text{HgBr}_2$	4800	1614	mix.	(1012)
$4\text{Na}_2\text{S} \cdot \text{HgS}$	aq.	2259	$\text{Na}_2\text{S} + \text{HgCl}_2$	(140)
$\text{NaCN} \cdot \text{Hg}(\text{CN})_2$	400	-149	mix.	(1009)
$2\text{NaCN} \cdot \text{Hg}(\text{CN})_2$	600	-32	mix.	(1009)
$\text{NaCl} \cdot \text{Hg}(\text{CN})_2$	1000	134	mix.	(1009)
$\text{NaCl} \cdot \text{Hg}(\text{CN})_2 \cdot \frac{1}{2}\text{H}_2\text{O}$	c	526	-33.9 <sup>15</sup>	(1009)
$\text{NaBr} \cdot \text{Hg}(\text{CN})_2$	1000	90	mix.	(1009)
$\text{NaBr} \cdot \text{Hg}(\text{CN})_2 \cdot 2\text{H}_2\text{O}$	c	713.1	-50.5 <sup>15</sup>	(1009)
$\text{NaI} \cdot \text{Hg}(\text{CN})_2$	1000	35	mix.	(1009)
$\text{NaI} \cdot \text{Hg}(\text{CN})_2 \cdot 2\text{H}_2\text{O}$	c	655	-48 <sup>15</sup>	(1009)
$\text{Na}_2\text{O} \cdot \text{CuO}_2$	c	684	Cu + $\text{Na}_2\text{O}_2$	(712)
$\text{Na}_2\text{O} \cdot \text{Ag}_2\text{O}_2$ (?) (from Ag and $\text{Na}_2\text{O}_2$ )	c	601	Ag + $\text{Na}_2\text{O}_2$	(712)
$\text{Na}_2\text{Ag}(\text{S}_2\text{O}_3)_2$	c	1881	$\text{AgNO}_3$ + $\text{Na}_2\text{S}_2\text{O}_3$	(369)
$\text{NaAg}(\text{CN})_2$	500	-18.2	$\text{AgCN}$ + $\text{NaCN}$	(1011)
$\text{Na}_2\text{Ag}(\text{CN})_2$	1200	78	$\text{AgCN}$ + $\text{NaCN}$	(1011)
$\text{NaClO}_2$ + $\text{AgClO}_2$ (solid solutions)	c			(371)
$\text{Na}_2\text{PtCl}_6$	c	950	42; analogy	
	aq.	992	$\text{Na}_2\text{PtCl}_6$ +	(976)
			$\text{CuCl}_2$ &	
$\text{Na}_2\text{PtCl}_6$	c	1138	35.6 <sup>18</sup> <sub>800</sub>	(976)
	aq.	1173	+Co	(976)



Formula	State	Q, kj	Method	Lit.
<b>Sodium.—(Continued)</b>				
$\text{Na}_2\text{PtCl}_6 \cdot 2\text{H}_2\text{O}$	c	1747	$-0.8^{18}_{800}$	(976)
$\text{Na}_2\text{PtCl}_6 \cdot 6\text{H}_2\text{O}$	c	2935	$-44.4^{18}_{900}$	(976)
$\text{Na}_2\text{PtBr}_6$	c	924	$41.6^{18}_{800}$	(976)
	aq.	966	+Co	(976)
$\text{Na}_2\text{PtBr}_6 \cdot 6\text{H}_2\text{O}$	c	2719	$-36^{18}_{800}$	(976)
$\text{Na}_2\text{PtI}_6$	aq.	699	+Co	(816)
$\text{Na}_2\text{RhCl}_6$	c	1426	$32.2^{18}_{6000}$	(453)
	aq.	1458	+Co	(453)
$\text{Na}_2\text{RhCl}_6 \cdot 12\text{H}_2\text{O}$	c	4978	$-86.0^{17}_{6000}$	(453)
$\text{Na}_2\text{PdCl}_6$	aq.	1014	ions	
$\text{Na}_2\text{MnO}_4$	c	1120	$\text{Mn} + \text{Na}_2\text{O}_2$	(712)
$\text{Na}_2\text{SO}_4 \cdot \text{MnSO}_4$	c	2406	54	(458)
	aq.	2460	mix.	(458)
$\text{Na}_2\text{SO}_4 \cdot \text{MnSO}_4 \cdot 2\text{H}_2\text{O}$	c	2601	13	(458)
$\text{Na}_2\text{SO}_4 \cdot \text{MnSO}_4 \cdot 6\text{H}_2\text{O}$	c	4218	-41	(458)
$\text{Na}_2\text{FeCO}(\text{CN})_6$	c	522	$20^{13}_{3600}$	(711)
	aq.	542	N	(747, 748)
$\text{Na}_2\text{FeCO}(\text{CN})_6 \cdot 7\text{H}_2\text{O}$	c	2577	$-31^{17}_{6000}$	(747, 748)
$\text{Na}_2\text{CoO}_2$	c	833	$\text{Co} + \text{Na}_2\text{O}_2$	(712)
$2\text{NaBr} \cdot \text{CoBr}_2$	900	1028	mix.	(1012)
$\text{Na}_2\text{Ni}(\text{CN})_6$	aq.	143	$\text{Ni}(\text{CN})_2 + \text{NaCN}$	(1011)
$\text{Na}_2\text{CrO}_4$	c	1325	$10.0^{11}_{800}$	(87, 707, 716)
	800	1335	N	(976)
	10	1350	$\rightarrow \text{Na}_2\text{CrO}_4 \cdot 10\text{H}_2\text{O}$	(731)
$\text{Na}_2\text{CrO}_4 \cdot 4\text{H}_2\text{O}$	c	2510	$-32^{11}_{1000}$	(86)
$\text{Na}_2\text{CrO}_4 \cdot 10\text{H}_2\text{O}$	c	4262	$-66.1^{11}_{1200}$	(86)
$\text{Na}_2\text{Cr}_2\text{O}_7$	aq.	1920.3	ions	(788)
$\text{Na}_2\text{MoO}_4(\text{I})$	c		Tr.; $61.1^{440}_{(\text{II})}$	(1091)
$\text{Na}_2\text{MoO}_4(\text{II})$	c	1514	$\text{Na}_2\text{O}_2 + \text{Mo}$	(712)
	400	1501	N	(788)
$\text{Na}_2\text{WO}_4(\text{I})$	c		Tr.; $39.8^{579}_{(\text{II})}$	(1091)
$\text{Na}_2\text{WO}_4(\text{II})$	c	1624	$\text{W} + \text{Na}_2\text{O}_2$	(707)
	aq.	1607	17; analogy	
$\text{Na}_2\text{UO}_4$	c	1759	$\text{U} + \text{Na}_2\text{O}_2$	(714)
$\text{Na}_2\text{U}_2\text{O}_7 \cdot 1\frac{1}{2}\text{H}_2\text{O}$	c	1910	$186\text{H}_2\text{SO}_4$	(820)
$(\text{Na}_2\text{O})_2\text{UO}_4$	aq.	5773	$\text{UO}_2\text{SO}_4 + \text{Na}_2\text{O}_2 + \text{H}_2\text{SO}_4$	(820)
$(\text{Na}_2\text{O})_2\text{UO}_4 \cdot 9\text{H}_2\text{O}$	c	5780	$\text{UO}_2\text{SO}_4 + \text{Na}_2\text{O}_2 + \text{H}_2\text{SO}_4$	(820)
$\text{NaVO}_3$	aq.	1180	$\text{V}_2\text{O}_5 + \text{NaHO}_2$	(891)
$\text{Na}_2\text{VO}_4$	c	1880	$\text{V} + \text{Na}_2\text{O}_2$	(714)
$\text{NaBO}_2$	300	969	N	(50, 59, 84, 976)
$\text{Na}_2\text{B}_4\text{O}_7$	c	3106	43	(48.1, 380, 361)
	aq.	3149	N	(50, 59, 976)
$\text{Na}_2\text{B}_4\text{O}_7 \cdot 10\text{H}_2\text{O}$	c	6119	$-108.2^{18}_{1600}$	(216, 360.5, 976)
$\text{Na}_2\text{BO}_3$ (?)	c	1405	$\text{B}_2\text{O}_3 + \text{Na}_2\text{O}_2$	(707)
	aq.	1622	N	(50, 59, 976)
$\text{NaAlO}_2$	c	1137	$\text{Na}_2\text{O} + \text{Al}_2\text{O}_3$	(716)
$3\text{NaF} \cdot \text{AlF}_3$	c	3113	$123(\text{us}\% \text{HF})$	(32)
	aq.	3256	mix.	(32)
$3\text{NaF} \cdot \text{AlF}_3 \cdot 3\frac{1}{2}\text{H}_2\text{O}$	c	4208	$-54.1$ ; &	(32)
$\text{NaCl} \cdot \text{AlCl}_3$	c	1134	$296^{18}_{800}$	(32)
$\text{NaCl} \cdot \text{AlCl}_3 \cdot 6\text{NH}_3$	c	1936	23.5	(32)
$3\text{NaCl} \cdot 2\text{AlCl}_3$	c	2693	$573.2^{18}_{2000}$	(32)
$\text{Na}_2\text{O} \cdot \text{Al}_2\text{O}_3 \cdot 3\text{SiO}_2$ (dehydr. natrolite)	c (?)	3699	$790(\text{us}\% \text{HF})$	(740)
$\text{Na}_2\text{O} \cdot \text{Al}_2\text{O}_3 \cdot 4\text{SiO}_2$ (dehydr. analcite)	c (?)	5733	$970(\text{us}\% \text{HF})$	(740)
$\text{Na}_2\text{CeO}_4$ (?)	c	(?)	$\text{Ce}_2\text{O}_3 + \text{Na}_2\text{O}_2$	(709)
$2\text{Na}_2\text{SO}_4 \cdot \text{CaSO}_4$	c	2782	$13.0^{1000}$	(30)
$2\text{Na}_2\text{SO}_4 \cdot \text{CaSO}_4 \cdot 2\text{H}_2\text{O}$	c	4731	$3.8^{1000}$	(30)
$\text{NaSrPO}_4 \cdot 9\text{H}_2\text{O}$	c	4802	N	(569)
$\text{NaSrAsO}_4 \cdot 9\text{H}_2\text{O}$	c	4295	N	(569)
$\text{NaBaPO}_4 \cdot 9\text{H}_2\text{O}$	c	4674	$\text{BaCl}_2 + \text{NaH}_2\text{PO}_4$	(569)
$\text{NaBaAsO}_4 \cdot 9\text{H}_2\text{O}$	c	4289	$\text{BaCl}_2 + \text{NaH}_2\text{AsO}_4$	(569)

Formula	State	Q, kj	Method	Lit.
<b>Potassium<sup>a</sup></b>				
K	c	0	Def.	
	gas	-86	$\rightarrow \text{c}$	(366*)
$\text{K}^+$	$\infty$	252.4	$\text{HCl}$ ; &	
$\text{K}_2\text{O}$	c	361	$314^{17}_{800}$	(40, 854)
$\text{K}_2\text{O}_2$	c	517	$182.3^{18}_{\text{H}_2\text{SO}_4}$	(410)
$\text{K}_2\text{O}_4$	c	550	$142.9\text{H}_2\text{SO}_4$	(418)
KH	c	59	dissoc.*	(579, 736*)
$\text{KOH}(\beta)$	c	426.9	$54.2^{21}_{176}$	(49, 55, 65, 219, 392, 976)
$\text{KOH}(\alpha)$	c		Tr.; $6.4^{248}_{(\beta)}$	(515)
(see also p. 161)	$\infty$	480.64	dil.	
	400	480.47	dil.	
	200	480.35	$\text{K} + \text{H}_2\text{O}$ ; &	(359, 558, 554, 976)
	100	480.30	dil.	(65, 408, 827, 867, 897, 976)
	50	480.29	dil.	
	25	480.18	dil.	
	15	479.80	dil.	
	9	478.73	dil.	
	7	477.61	dil.	
	5	475.10	dil.	
	3	468.85	dil.	
$\text{KOH} \cdot \frac{1}{2}\text{H}_2\text{O}$	c	678	$18.0^{21}_{176}$	(289, 392)
$\text{KOH} \cdot \text{H}_2\text{O}$	c	752	$14.9^{21}_{176}$	(219, 392)
$\text{KOH} \cdot 2\text{H}_2\text{O}$	c	1052	$-0.1^{11}_{170}$	(65, 219)
KF	c	561.2	$17.2^{15}_{110}$	(410, 465)
	400	578.4	N; &	(157, 465, 740, 976)
	5.76	576.8	dil.	(412)
	3.90	573.9	dil.	
$\text{KF} \cdot 2\text{H}_2\text{O}$	c	1159.7	$-9.0^{15}_{110}$	(412, 465)
$\text{KF} \cdot 4\text{H}_2\text{O}$	c	1748.7	-25.8	(412)
$\text{KHF}_2$	c	918	$-25^{15}_{400}$	(412, 464, 465)
	400	893	N; &	(464, 465, 976)
$\text{KF} \cdot 2\text{HF}$	c	1242	-33	(471)
$\text{KF} \cdot 3\text{HF}$	c	1561	-36	(471)
KCl	c	436.5	$-18.6^{18}_{200}$ ; &	(16, 157.5, 245, 290, 295, 312, 493, 623, 729, 777, 810, 840, 934, 976, 1006, 1046)
(see also p. 161)	gas	220	$\rightarrow \text{c}$	(366, 492*)
	$\infty$	417.99	dil.	(198, 245, 801.5, 823, 853, 827, 868, 890, 909, 934, 938, 1006)
	1000	417.91	dil.	
	500	417.88	dil.	

<sup>a</sup> Heats of solution of melted salt mixtures:

	Fresh melt	Old melt	Lit.
$\text{KCl} \cdot \text{NaCl}$	-20.2	-20.8 <sup>15</sup>	(157.5, 777, 1023)
$\text{KCl} \cdot 2\text{NaCl}$	-22.6 <sup>15</sup>	-25.1 <sup>15</sup>	
$2\text{KCl} \cdot \text{NaCl}$	-30.4 <sup>15</sup>	-35.7 <sup>15</sup>	
$\text{KI} \cdot \text{NaCl}$	-23.3 <sup>150</sup>		(48)
$\text{K}_2\text{SO}_4 \cdot \text{Na}_2\text{SO}_4$	-23 <sup>15</sup>	-21.2 <sup>10</sup>	
$\text{K}_2\text{SO}_4 \cdot 2\text{Na}_2\text{SO}_4$	-16.1 <sup>15</sup>	-15.1 <sup>10</sup>	
$2\text{K}_2\text{SO}_4 \cdot \text{Na}_2\text{SO}_4$	-55.7 <sup>15</sup>	-52.0 <sup>10</sup>	
$\text{K}_2\text{CO}_3 \cdot \text{Na}_2\text{CO}_3$	34.4 <sup>15</sup>	33.9 <sup>14</sup>	
$\text{K}_2\text{CO}_3 \cdot 2\text{Na}_2\text{CO}_3$	64.9 <sup>11</sup>	64.2 <sup>15</sup>	
$\text{K}_2\text{CO}_3 \cdot 3\text{Na}_2\text{CO}_3$	97.5 <sup>14</sup>	94.1 <sup>14</sup>	
$\text{K}_2\text{CO}_3 \cdot 4\text{Na}_2\text{CO}_3$	129.3 <sup>14</sup>	127.5 <sup>10</sup>	
$2\text{K}_2\text{CO}_3 \cdot \text{Na}_2\text{CO}_3$	55.3 <sup>15</sup>	55.5	
$3\text{K}_2\text{CO}_3 \cdot \text{Na}_2\text{CO}_3$	101 <sup>15</sup>	101 <sup>15</sup>	(157.5)

KCl·BrCl mixtures, partial heat of dilution (938).

Solid solutions of KCNS and NaCNS, heats of formation (1023).

KAuCl<sub>4</sub>, heat of dissociation (760.5).

KCl, HCl, partial heat content of HCl (500, 501).

$\text{K}_2\text{SO}_4 \cdot \text{CoSO}_4 \cdot 6\text{H}_2\text{O}$ ,  $\text{K}_2\text{SO}_4 \cdot \text{ZnSO}_4 \cdot 6\text{H}_2\text{O}$ ,  $\text{K}_2\text{SO}_4 \cdot \text{NiSO}_4 \cdot 6\text{H}_2\text{O}$ , heats of dehydration (262).



Formula	State	Q, kJ	Method	Lit.
<b>Potassium.—(Continued)</b>				
KCl.—(Continued)	200	417.93	N	(50, 742, 868,°)
	100	418.02	dil.	(978)
	50	418.73	dil.	
	25	419.53	dil.	
KClO	400	360.5	KOH + Cl <sub>2</sub> ;	(976)
			&	
KClO <sub>2</sub>	c	376.1	-43.0 <sup>18</sup> <sub>400</sub>	(55, 216, 428, 934, 947, 976, 1019)
	∞	332.2	dil.	(934†)
	500	332.9	dil.	
	400	333.1	N; &	(947, 976)
	250	333.8	dil.	
	125	334.9	dil.	
KClO <sub>4</sub>	c	469	+NH <sub>4</sub> C <sub>6</sub> H <sub>7</sub> -(NO <sub>2</sub> ) <sub>2</sub> O	(174)
	∞	415.3	dil.	(934†)
	1000	417.0	dil.	(761)
	500	421	dil.	
	sat.	420	-49.0	(174, 761 934†)
KBr	c	393.5	-21.2 <sup>13</sup> <sub>200</sub> ; &	(55, 67; 157.5,° 245,† 976, 1024)
	gas	184	→ c	(366*)
	∞	372.0	ions	
	200	372.30	N; &	(63, 868,° 976)
	50	372.5	dil.	(324,† 890,† 976)
	10	375.4	dil.	(976)
KBr <sub>2</sub>	aq.	382	KBr + Br <sub>2</sub> *	(648*)
KBr <sub>3</sub>	aq.	401	KBr <sub>2</sub> + Br <sub>2</sub> *	(648*)
KBrO	aq.	344	ions	
KBrO <sub>3</sub>	c	347.8	-42 <sup>18</sup> <sub>400</sub>	(81, 934,† 976)
	∞	305.0	dil.	(934)
	500	305.6	dil.	
	400	305.9	N	(976)
	250	306.0	dil.	
KBr.KCl(solid solutions)				(157.5, 959, 1023)
KI	c	329.6	-21.4 <sup>18</sup> <sub>400</sub>	(111, 976)
	gas	134	→ c	(366°)
	∞	308.1	ions	(55, 909)
	200	308.35	N	(63, 868,° 976)
	100	308.5	dil.	(324)
KI <sub>2</sub>	aq.	301	I <sub>2</sub> + KI, &	(1, 94, 811)
KIO	aq.	331	KOH + I <sub>2</sub>	(82, 924, 928)
KIO <sub>3</sub>	c	508.4	-28.3 <sup>18</sup> <sub>400</sub>	(82, 934, 976)
	∞	479.2	dil.	(934)
	500	479.7	dil.	
	400	480.1	N; &	(80, 82, 976)
	250	480.7	dil.	
KIO <sub>4</sub>	aq.	409	N	(976)
K <sub>2</sub> IO <sub>6</sub>	aq.	1186.7	N	(976)
K <sub>2</sub> IO <sub>8</sub>	aq.	1871	N	(80, 976)
KH <sub>2</sub> IO <sub>6</sub>	400	981	N	(976)
KIO <sub>3</sub> .HIO <sub>3</sub>	c	758	-49 <sup>12</sup> <sub>800</sub>	(82)
	aq.	709	mix.	(976)
K <sub>2</sub> H <sub>2</sub> IO <sub>6</sub>	aq.	1265	N	(80, 976)
K <sub>2</sub> H <sub>2</sub> IO <sub>8</sub>	aq.	1473	N	(80, 976)
KI.KCl(fresh melt)	c	765	-38	(45, 157.5)
KI.KBr(fresh melt)	c	718	-38	(157.5, 1023)
K <sub>2</sub> S	c	369	94	(359, 856, 897)
	400	462.8	dil.	(897)
	200	463.1	N; &	(897, 976)
	100	463.4	dil.	
	50	464.1	dil.	
	20	464.5	dil.	
	10	459.3	dil.	
	7	453.6	dil.	
K <sub>2</sub> S.2H <sub>2</sub> O	c	1019	16 <sup>18</sup> <sub>1300</sub>	(897)
K <sub>2</sub> S.5H <sub>2</sub> O	c	1915	-22 <sup>18</sup> <sub>1000</sub>	(897)
K <sub>2</sub> S <sub>4</sub>	c	476	5 <sup>10</sup> <sub>100</sub>	(897)
	sq.	481	+HI	(897)

Formula	State	Q, kJ	Method	Lit.
<b>Potassium —(Continued)</b>				
K <sub>2</sub> S <sub>4</sub> .4H <sub>2</sub> O	c	633	-9.2 <sup>12</sup>	(897)
K <sub>2</sub> S <sub>4</sub> .2H <sub>2</sub> O	c	1085	-31 <sup>12</sup>	(897)
K <sub>2</sub> SO <sub>3</sub>	c	1112	6 <sup>12</sup> <sub>300</sub> ; &	(116, 669)
	600	1119	N; &	(116, 976)
K <sub>2</sub> SO <sub>3</sub> .H <sub>2</sub> O	c	1400	5 <sup>300</sup>	(116)
K <sub>2</sub> SO <sub>4</sub> (I)	c		Tr., 10.75 <sup>569</sup> (II)	(1091)
K <sub>2</sub> SO <sub>4</sub> (II)	c	1417.1	-27.4 <sup>18</sup> <sub>400</sub>	(49, 157.5° 245, 255, 259, 265,° 810, 909, 976, 978,° 1006°)
	∞	1389.1	ions	
	800	1389.5	dil.	(245,† 890†)
	400	1389.7	dil.	(1006°)
	200	1390.8	N, &	(748, 976)
	100	1392.4	dil.	
	50	1394.9	dil.	
K <sub>2</sub> S <sub>2</sub> O <sub>8</sub>	c	1116	-21 <sup>10</sup> <sub>800</sub>	(117, 123, 669)
	aq	1095	N	(976)
K <sub>2</sub> S <sub>2</sub> O <sub>8</sub> .H <sub>2</sub> O	c	1407	-26 <sup>14</sup>	(999)
K <sub>2</sub> S <sub>2</sub> O <sub>8</sub>	c	1500	-47.0 <sup>13</sup> <sub>450</sub>	(118)
	600	1452	N	(118)
K <sub>2</sub> S <sub>2</sub> O <sub>8</sub> .4H <sub>2</sub> O(?)	c	1643	-47.5 <sup>13</sup> <sub>450</sub>	(118)
K <sub>2</sub> S <sub>2</sub> O <sub>8</sub>	c	1707.1	dissoc.	(669, 976)
	500	1653	-54.4 <sup>19</sup> <sub>600</sub>	(976)
K <sub>2</sub> S <sub>2</sub> O <sub>7</sub>	c	1954	-16	(53)
	aq	1938	dissoc.	(53)
K <sub>2</sub> S <sub>2</sub> O <sub>6</sub>	c	1861	-61 <sup>9</sup> <sub>3200</sub>	(135°)
	aq.	1800	BaSO <sub>4</sub> + K <sub>2</sub> SO <sub>4</sub> ; &	(135°)
K <sub>2</sub> S <sub>2</sub> O <sub>5</sub>	c	1650	-52.1 <sup>18</sup> <sub>600</sub> ; &	(131, 669, 976)
	aq.	1598	+Br <sub>2</sub>	(131)
K <sub>2</sub> S <sub>4</sub> O <sub>6</sub>	c	1655	-55.0 <sup>17</sup> <sub>600</sub>	(669)
	aq.	1600	ions	
K <sub>2</sub> S <sub>5</sub> O <sub>6</sub>	c	1666	-42	(669)
	aq.	1624	ions	
K <sub>2</sub> S <sub>5</sub> O <sub>6</sub> .4H <sub>2</sub> O	c	2108	-55 <sup>10</sup> <sub>2000</sub>	(131)
KHS	400	267.7	dil.	(897)
	200	267.8	N	(976)
	50	269.3	dil.	
	20	272.1	dil.	
	10	272.4	dil.	
	6	268.6	dil.	
KHS.4H <sub>2</sub> O	c	336	3.2 <sup>17</sup> <sub>1000</sub>	(897)
KHSO <sub>3</sub>	400	869.4	N	(116, 976)
KHSO <sub>4</sub> (III)	c	1142	-15.9 <sup>17</sup> <sub>200</sub>	(52, 255, 459, 976)
			Tr.: 2.0 <sup>180</sup> (III)	(235°)
			Tr.: 0.40 <sup>154</sup> (II)	(235°)
KHSO <sub>4</sub> (II)	c			(52, 976)
KHSO <sub>4</sub> (I)	c			
KHSO <sub>4</sub>	800	1128.9	dil.	
	400	1127.2	dil.	
	200	1126.1	N; &	(52, 976)
	100	1125.5	dil.	
	50	1125.4	dil.	
	20	1125.6	dil.	(976)
KI.4SO <sub>3</sub>	c	1654	dissoc.*	(342°)
K <sub>2</sub> Se	c	357	36 <sup>12</sup> <sub>1800</sub>	(350)
	aq.	393	N	(350)
K <sub>2</sub> Se.9H <sub>2</sub> O	c	3048	-80 <sup>14</sup> <sub>4000</sub>	(350)
K <sub>2</sub> Se.14H <sub>2</sub> O	c	4484	-85 <sup>13</sup> <sub>4000</sub>	(350)
K <sub>2</sub> Se.19H <sub>2</sub> O	c	5952	-123 <sup>14</sup>	(350)
KHSe	aq.	198	N	(350)
K <sub>2</sub> TeO <sub>3</sub>	aq.	1085	N	(696)
K <sub>2</sub> TeO <sub>4</sub>	aq.	1227	N	(696)
KNO <sub>2</sub>	aq.	359	N; &	(52, 954)
KNO <sub>2</sub> (I)	c		Tr.: 2.6 <sup>126</sup> (III)	(45.2, 234°)
KNO <sub>2</sub> (III)	c		Tr.: 4.9 <sup>129</sup> (II)	(45.2, 234°)
KNO <sub>2</sub> (II)	c			(9, 52, 294,°†)
			-35.4 <sup>18</sup> <sub>200</sub>	
KNO <sub>3</sub>	c	497.1	dil.	493, 624, 729, 816,° 909,° 934,†
	∞	460.81	dil.	
	1000	460.94	dil.	
	500	461.06	dil.	

(see also p. 162)



Formula	State	Q, kj	Method	Lit.
<b>Potassium.—(Continued)</b>				
$\text{KNO}_3(\text{dl})$ —(Continued)				976, 978,° 1006,° 1046°)
	200	461.69	N; &	(82, 868,° 976)
	100	462.74	dil.	(82, 198, 827,° 867,° 890, 934†)
	50	464.49	dil.	(1006°)
	25	467.17	dil.	
	sat.	468.0	dil.	(294, 934†)
$\text{K}_2(\text{NO})_2$ .....	aq.	489	$\text{Sr}(\text{NO})_2 + \text{K}_2\text{SO}_4$	(133)
$\text{KNH}_2$ .....	c	73	dissoc.; &	(889)
$\text{KBr} \cdot 4\text{NH}_3$ .....	c	696	dissoc.*	(187*)
$\text{KI} \cdot 4\text{NH}_3$ .....	c	641	dissoc.*	(187*)
$\text{KI} \cdot 6\text{NH}_3$ .....	c	794	dissoc.*	(187*)
$\text{K}_3\text{PO}_4$ .....	aq.	2006	N	(976)
$\text{KH}_2\text{PO}_4$ .....	aq.	849	N	(976)
$\text{KH}_2\text{PO}_4$ .....	aq.	1214	N	(976)
$\text{KH}_2\text{PO}_4$ .....	c	1557	-20	(468)
	aq.	1537	N	(976)
$\text{K}_2\text{HPO}_4$ .....	aq.	1465	N	(976)
$\text{K}_2\text{HPO}_4$ .....	aq.	1783	N	(976)
$\text{K}_2\text{AsO}_4$ .....	400	1631	N	(976)
$\text{KH}_2\text{AsO}_4$ .....	800	963	N	(976)
$\text{KH}_2\text{AsO}_4$ .....	c	1175	-20	(468)
	400	1155	N	(976)
$\text{K}_2\text{HASO}_4$ .....	400	1160	N	(976)
$\text{K}_2\text{HASO}_4$ .....	400	1402	N	(976)
$\text{K}_2\text{CO}_3$ .....	c	1150.7	$27.2^{18}_{400}$ ; &	(53, 187.5,° 614, 777, 976)
	400	1177.9	dil.	(976)
	200	1178.5	N; &	(52, 742, 976)
	100	1179.3	dil.	(405, 890,† 976)
	50	1180.5	dil.	
	10	1181.0	dil.	
$\text{K}_2\text{CO}_3 \cdot \frac{1}{2}\text{H}_2\text{O}$ .....	c	1303.0	$17.9^{18}_{400}$	(976)
$\text{K}_2\text{CO}_3 \cdot \frac{1}{2}\text{H}_2\text{O}$ .....	c	1608.7	$-1.6^{18}_{400}$	(55,° 976)
$\text{K}_2\text{C}_2\text{O}_4$ .....	c	1341	-20	(56)
	3200	1321.6	dil.	(318)
	1600	1321.7	dil.	(318)
	800	1322.0	N; &	(56, 976)
	400	1322.5	dil.	(318)
	200	1323.8	dil.	(318)
	133	1325.1	dil.	(318)
$\text{K}_2\text{C}_2\text{O}_4 \cdot \text{H}_2\text{O}$ .....	c	1639.0	$-31.0^{18}_{800}$	(976)
$7\text{K}_2\text{CO}_3 \cdot 2\text{CO}_2 \cdot 9\frac{1}{2}\text{H}_2\text{O}$ .....	c	1233.4	$-91.4^{18}_{1500}$	(406)
$\text{KHCO}_3$ .....	c	669.1	$-3.9^{11}_{320}$	(55)
	400	665.2	N	(55, 68, 976)
$\text{KHCO}_3$ .....	c	968	$-22.3^{18}_{320}$ ; &	(53, 264,* 406, 632*)
	200	945	N; &	(52, 742, 976)
$\text{KCH}_3\text{O}$ .....	$\text{CH}_3\text{OH}$	464	$\text{K} + \text{CH}_3\text{OH}$	(376)
$\text{KHC}_2\text{O}_4$ .....	c	1107	-40	(469)
	400	1067.3	N	(56, 976)
$\text{KC}_2\text{H}_3\text{O}_2$ .....	c	730.2	$14.0^{20}_{200}$	(56, 976)
	400	744.2	N	(49, 976)
	200	744.0	dil.	(976)
	100	743.7	dil.	
	50	743.2	dil.	
	25	742.5	dil.	
	10	740.7	dil.	
	5	737.4	dil.	
$\text{KC}_2\text{H}_3\text{O}_2$ .....	$\text{C}_2\text{H}_5\text{OH}$	481.9	$\text{K} + \text{C}_2\text{H}_5\text{OH}$	(310, 376)
$\text{KHC}_2\text{O}_4 \cdot \text{H}_2\text{C}_2\text{O}_4$ .....	c	1946	-66	(489)
$\text{KHC}_2\text{H}_3\text{O}_2$ .....	c	1545	-43HCl	(468, 588)
	aq.	1497	N	(56, 134, 963)
$\text{K}_2\text{C}_4\text{H}_4\text{O}_6$ .....	c	1755	$-11.9^{18}_{400}$	(56, 134, 468, 810)
	aq.	1743	N	(56, 134, 180, 963)
$\text{K}_2\text{C}_4\text{H}_4\text{O}_6 \cdot \frac{1}{2}\text{H}_2\text{O}$ .....	c	1912	$-25.7^{18}_{400}$	(56, 810, 963)
$\text{K}_2\text{C}_4\text{H}_4\text{O}_6 \cdot 2\text{H}_2\text{O}$ .....	c	2363	-43.6	(963)
$\text{KCN}$ .....	c	118	$-12^{18}_{300}$	(58, 70, 976)
	200	105	N; &	(70, 139, 976)
$\text{KCNO}$ .....	c	419	$-21.6^{30}_{400}$	(58)
	aq.	397	+HCl; &	(137)

Formula	State	Q, kj	Method	Lit.
<b>Potassium.—(Continued)</b>				
$\text{K}_2\text{C}_2\text{N}_2\text{O}_2$ .....	c	1341	$-25^{21}_{6000}$	(626)
	aq.	1317	N	(626)
$\text{KH}_2\text{C}_2\text{N}_2\text{O}_2$ .....	c	938	$-35.9^{1500}$	(626)
	aq.	902	N	(626)
$\text{KHC}_2\text{N}_2\text{O}_2 \cdot \text{H}_2\text{O}$ .....	c	1233	$-45.4^{21}_{1500}$	(626)
$\text{K}_2\text{HC}_2\text{N}_2\text{O}_2$ .....	c	1114	-26 <sub>1665</sub>	(626)
	aq.	1088	N	(626)
$\text{KCNS}$ .....	c	227	-51 <sub>100</sub>	(555, 1023)
	aq.	176	$\text{K}_2\text{S}_2 + \text{KCN}; \&$	(555, 1023)
$\text{KHCN}$ .....	aq.	159	N	(626)
$\text{KCNS} \cdot \text{SO}_2$ .....	c	562	dissoc.*	(342*)
$2\text{KCNS} \cdot \text{SO}_2$ .....	c	792	dissoc.*	(342*)
$\text{KSbOC}_4\text{H}_4\text{O}_6$ .....	c	1453	2	(469)
$\text{KSbOC}_4\text{H}_4\text{O}_6$ .....	c	1768	-21 <sub>12</sub>	(469)
	aq.	1741	N	(469)
$\text{KSbOC}_4\text{H}_4\text{O}_6 \cdot \frac{1}{2}\text{H}_2\text{O}$ .....	c	1907	-22 <sub>12</sub>	(469)
$\text{K}_2\text{SiF}_6$ .....	c	2854	N	(1001)
	aq.	2794	N; &*	(1090*)
$\text{K}_2\text{SnCl}_6$ .....	c	1507.3	$-14.1^{12}_{800}$	(976)
	600	1493.2	$\text{KCl} + \text{SnCl}_4$	(976)
$\text{K}_2\text{SnCl}_6 \cdot \text{H}_2\text{O}$ .....	c	1520	$-56.2^{18}_{600}$	(976)
$\text{KCl} \cdot \text{PbCl}_2 \cdot \frac{1}{2}\text{H}_2\text{O}$ .....	c	896.0	$\text{KCl} + \text{PbCl}_2$	(246*)
$\text{KCl} \cdot 2\text{PbCl}_2$ .....	c	1162.8	$\text{KCl} + \text{PbCl}_2$	(246*)
$2\text{KI} \cdot \text{PbI}_2(\text{melt})$ .....	c	838	-46.1	(111)
$2\text{KI} \cdot \text{PbI}_2 \cdot 2\text{H}_2\text{O}$ .....	c	1429	$-66.2^{18}_{1000}$	(111)
$4\text{KI} \cdot 3\text{PbI}_2(\text{fresh melt})$ .....	c	1839	-81 <sub>1400</sub>	(111)
$4\text{KI} \cdot 3\text{PbI}_2 \cdot 6\text{H}_2\text{O}$ .....	c	3608	$-132^{18}_{3000}$	(111)
$\text{K}_2\text{SO}_4 \cdot \text{PbSO}_4$ .....	c	2336.1	$\text{K}_2\text{SO}_4 + \text{PbSO}_4; \&$	(30, 245*)
$\text{KCl} \cdot \text{ThCl}_4 \cdot 9\text{H}_2\text{O}$ .....	c	4621	12.8	(268)
$2\text{KCl} \cdot \text{ThCl}_4$ .....	c	2313	1673	(268)
$\text{K}_2\text{Zn}(\text{SO}_4)_2$ .....	c	2394	$33.1^{18}_{600}$	(458, 976)
$\text{K}_2\text{Zn}(\text{SO}_4)_2 \cdot 2\text{H}_2\text{O}$ .....	c	2998	$2.0^{18}_{600}$	(976)
$\text{K}_2\text{Zn}(\text{SO}_4)_2 \cdot 6\text{H}_2\text{O}$ .....	c	4194	$-49.4^{18}_{600}$	(458, 976)
$2\text{KCN} \cdot \text{Zn}(\text{CN})_2$ .....	c	122	$63^{16}_{300}$	(140, 638*)
$8\text{KCN} \cdot \text{Zn}(\text{CN})_2$ .....	aq.	825	mix.	(139)
$\text{KHg}_2$ .....	c	60	$193\text{HCl}$	(140)
$\text{KHg}_2$ .....	c	121	$133\text{HCl}$	(89)
$\text{K}_2\text{Hg}_2$ .....	c	167	$341\text{HCl}$	(89)
$\text{KHg}_{2.5}$ .....	liq.	109.0	$\text{K} + \text{Hg}$	(638,* 927)
$\text{KCl} \cdot \text{HgCl}_2$ .....	c	669	$-40^{14}_{700}$	(106)
	aq.	629	mix.	(106)
$\text{KCl} \cdot \text{HgCl}_2 \cdot \text{H}_2\text{O}$ .....	c	963	$-47.3^{14}_{700}$	(106)
$2\text{KCl} \cdot \text{HgCl}_2$ .....	c	1116	$-62.9^{14}_{1000}$	(106)
	400	1053	mix.	(976)
$2\text{KCl} \cdot \text{HgCl}_2 \cdot \text{H}_2\text{O}$ .....	c	1408	$-68.6^{18}_{600}$	(106, 976)
$4\text{KCl} \cdot 3\text{HgCl}_2$ .....	c	2449	-141 <sub>14</sub>	(106)
$4\text{KCl} \cdot 3\text{HgCl}_2 \cdot 3\text{H}_2\text{O}$ .....	aq.	2308	mix.	(106)
$\text{KBr} \cdot \text{HgBr}_2$ .....	c	577	-11 <sub>14</sub>	(106)
	4200	533.6	mix.	(106, 1012)
$\text{KBr} \cdot \text{HgBr}_2 \cdot \text{H}_2\text{O}$ .....	c	877	$-25\text{KBr}(100)$	(106, 976)
$2\text{KBr} \cdot \text{HgBr}_2$ .....	c	962	$-40.8^{18}_{650}$	(106, 976)
	4400	910	mix.	(106, 1012)
	660	921	mix.	(976)
$4\text{KBr} \cdot \text{HgBr}_2$ .....	4800	1661	mix.	(1012)
$\text{KI} \cdot \text{HgI}_2$ .....	c	444	+aq.	(106)
$\text{KI} \cdot \text{HgI}_2 \cdot \text{H}_2\text{O}$ .....	c	731	+aq.	(106)
$2\text{KI} \cdot \text{HgI}_2$ .....	c	778	$-41.0^{18}_{800}$	(976)
	600	737	$\text{HgI}_2 + \text{KI}$	(976)
$3\text{KI} \cdot \text{HgI}_2$ .....	aq.	1048	$\text{HgI}_2 + \text{KI}$	(109)
$6\text{KI} \cdot \text{HgI}_2$ .....	aq.	1980	$\text{HgI}_2 + \text{KI}$	(109)
$\text{KCN} \cdot \text{Hg}(\text{CN})_2$ .....	400	-137	mix.	(1008)
$2\text{KCN} \cdot \text{Hg}(\text{CN})_2$ .....	c	52	-59	(106)
	000	-7	mix.	(140)
$\text{KCl} \cdot \text{Hg}(\text{CN})_2$ .....	c	184	-38	(109)
	500	146	mix.	(109)
$\text{KCl} \cdot \text{Hg}(\text{CN})_2 \cdot \text{H}_2\text{O}$ .....	c	476	-43	(109)
$\text{KCl} \cdot 2\text{Hg}(\text{CN})_2$ .....	1000	-126	mix.	(109)
$2\text{KCl} \cdot \text{Hg}(\text{CN})_2$ .....	600	565	mix.	(109)
$4\text{KCl} \cdot \text{Hg}(\text{CN})_2$ .....	800	1402	mix.	(109)
$8\text{KCl} \cdot \text{Hg}(\text{CN})_2$ .....	1200	3075	mix.	(109)



Formula	State	Q, kj	Method	Lit.
Potassium.—(Continued)				
KBr.Hg(CN) <sub>2</sub>	c	151	-50 <sup>14</sup>	(106)
KBr.Hg(CN) <sub>2</sub> .1½H <sub>2</sub> O	c	500	102	mix. (106)
KBr.2Hg(CN) <sub>2</sub>	c	584	-53 <sup>14</sup>	(106, 1009)
2KBr.Hg(CN) <sub>2</sub>	1000	-170	mix. (106)	
4KBr.Hg(CN) <sub>2</sub>	600	475	mix. (106)	
8KBr.Hg(CN) <sub>2</sub>	800	1222	mix. (106)	
8KBr.Hg(CN) <sub>2</sub>	1200	2714	mix. (106)	
KI.Hg(CN) <sub>2</sub>	c	97	-50 <sup>14</sup>	(106)
KI.Hg(CN) <sub>2</sub> .½H <sub>2</sub> O	c	500	47	mix. (106)
KI.2Hg(CN) <sub>2</sub>	c	171	-52 <sup>14</sup>	(106)
2KI.Hg(CN) <sub>2</sub>	1000	-224	mix. (106)	
4KI.Hg(CN) <sub>2</sub>	600	360	mix. (106)	
8KI.Hg(CN) <sub>2</sub>	800	980	mix. (106)	
8KI.Hg(CN) <sub>2</sub>	1200	2216	mix. (106)	
KCl.CuCl <sub>2</sub>	c	662.7	14.9 <sup>16</sup> <sub>200</sub>	(1022)
2KCl.CuCl <sub>2</sub>	c	1016	KCl + CuCl <sub>2</sub> *	(246)
2KCl.CuCl <sub>2</sub>	c	1103.2	-5.9 <sup>18</sup> <sub>800</sub>	(226)
2KCl.CuCl <sub>2</sub> .2H <sub>2</sub> O	c	1696	-26.7 <sup>18</sup> <sub>800</sub>	(226, 360, 1022)
K <sub>2</sub> SO <sub>4</sub> .CuSO <sub>4</sub> (α) (prepared below 120°)	c	2164	40.6 <sup>18</sup> <sub>600</sub>	(810, 976)
K <sub>2</sub> SO <sub>4</sub> .CuSO <sub>4</sub> (β) (prepared bet. 120-200°)	c	2179	26	(360.5, 808)
K <sub>2</sub> SO <sub>4</sub> .CuSO <sub>4</sub> (fused)	c	2169	35.2	(458, 808)
K <sub>2</sub> SO <sub>4</sub> .CuSO <sub>4</sub> .2H <sub>2</sub> O	c	2782	-4.8 <sup>18</sup> <sub>600</sub> ; &	(261, 976)
K <sub>2</sub> SO <sub>4</sub> .CuSO <sub>4</sub> .6H <sub>2</sub> O	c	3978	-56.4 <sup>18</sup> <sub>800</sub>	(355, 360.5, 458, 810)
K <sub>2</sub> Cu(CO <sub>3</sub> ) <sub>2</sub> (V)	c	1788	49.5HCl	(814)
K <sub>2</sub> Cu(CO <sub>3</sub> ) <sub>2</sub> (II)	c	1777	60.5HCl	(814)
K <sub>2</sub> Cu(CO <sub>3</sub> ) <sub>2</sub> (IV)	c	1786	51.9HCl	(814)
KI.AgI	c	408	+aq.	(112)
KI.AgI.½H <sub>2</sub> O	c	527	+aq.	(112)
2KI.AgI.½H <sub>2</sub> O	c	865	+aq.	(112)
3KI.AgI	c	1071	+aq.	(112)
3KI.AgI.½H <sub>2</sub> O	c	1193	+aq.	(112)
KAg(CN) <sub>2</sub>	c	28	-35.8 <sup>11</sup> <sub>400</sub>	(55, 113)
	500	-7	KCN + AgCN	(140, 1011)
K <sub>2</sub> Ag(CN) <sub>2</sub>	1200	101	KCN + AgCN	(140, 1011)
KAu(CN) <sub>2</sub>	aq.	26	AuCl + KCN(s)	(1078)
K <sub>2</sub> IrCl <sub>6</sub>	c	1170	disso.*	(451, 453)
	aq.	1117	-13 <sup>14</sup>	(453)
K <sub>2</sub> IrCl <sub>6</sub>	c	1530	K <sub>2</sub> IrCl <sub>6</sub> + Co	(453, 454)
K <sub>2</sub> PtCl <sub>6</sub>	c	1066	-50.7; &	(976)
	aq.	1015	+Co; &	(976)
K <sub>2</sub> PtCl <sub>6</sub>	c	1254	Na <sub>2</sub> PtCl <sub>6</sub> + KCl; &	(976)
	aq.	1198	-57.6	(976)
K <sub>2</sub> PtBr <sub>6</sub>	c	925	-44.2	(976)
	aq.	881	+Co; &	(816, 976)
K <sub>2</sub> PtBr <sub>6</sub>	c	1040	-51.3; &	(976)
	aq.	988	+Co; &	(976)
K <sub>2</sub> PdCl <sub>6</sub>	c	1094	-57.0 <sup>19</sup> <sub>300</sub>	(976)
	aq.	1037	+Co; &	(556, 976)
K <sub>2</sub> PdCl <sub>6</sub>	c	1214	-63	(976)
	aq.	1151	+CuCl; &	(976)
K <sub>2</sub> PdBr <sub>6</sub>	aq.	872	Pd + KBr + Br <sub>2</sub>	(556)
KMnO <sub>4</sub>	c	813	-43.5 <sup>18</sup> <sub>1000</sub> ; &	(55, 723, 976)
	600	769	+H <sub>2</sub> O <sub>2</sub> ; &	(55, 976)
KFe(SO <sub>4</sub> ) <sub>2</sub>	aq.	2038	mix.	(59, 976)
KFe(SO <sub>4</sub> ) <sub>2</sub> .12H <sub>2</sub> O	c	5539	-67	(259)
K <sub>2</sub> Fe(SO <sub>4</sub> ) <sub>2</sub> .4H <sub>2</sub> O	c	3551	disso.*	(262)
K <sub>2</sub> Fe(SO <sub>4</sub> ) <sub>2</sub> .6H <sub>2</sub> O	c	4123	-46	(458)
K <sub>2</sub> Fe(CN) <sub>6</sub>	c	205	-60.1 <sup>13</sup> <sub>400</sub>	(555)
	aq.	144	+Br <sub>2</sub> ; &	(555)
K <sub>2</sub> Fe(CN) <sub>6</sub>	c	551	-52 <sup>17</sup> <sub>1000</sub>	(55, 555, 910)
	aq.	499	N	(277, 555, 743)
K <sub>2</sub> Fe(CN) <sub>6</sub> .3H <sub>2</sub> O	c	1427	-69 <sup>17</sup> <sub>1000</sub>	(55, 910)
K <sub>2</sub> FeCO(CN) <sub>5</sub>	c	598	-22 <sup>17</sup> <sub>2200</sub>	(746)
	aq.	576	N	(746)
K <sub>2</sub> FeCO(CN) <sub>5</sub> .3½H <sub>2</sub> O	c	1623	-46 <sup>18</sup> <sub>2200</sub>	(746)

Formula	State	Q, kj	Method	Lit.
Potassium.—(Continued)				
KH <sub>2</sub> Fe(CN) <sub>6</sub>	aq.	-364	N	(555)
KH <sub>2</sub> Fe(CN) <sub>6</sub>	aq.	-259	N	(277, 743)
K <sub>2</sub> HFe(CN) <sub>6</sub>	aq.	-109	N	(555)
K <sub>2</sub> H <sub>2</sub> Fe(CN) <sub>6</sub>	aq.	-6	N	(277, 555, 743)
K <sub>2</sub> HFe(CN) <sub>6</sub>	aq.	247	N	(277, 555, 743)
K <sub>2</sub> Ni(CN) <sub>4</sub>	aq.	166	Ni(CN) <sub>2</sub> + KCN	(1011)
K <sub>2</sub> CrO <sub>4</sub> (I)	c		Tr.; 17.0 <sup>664</sup> <sub>(II)</sub>	(1091)
K <sub>2</sub> CrO <sub>4</sub> (II)	c	1379	-22.0 <sup>664</sup> <sub>1000</sub>	(458, 733)
K <sub>2</sub> Cr <sub>2</sub> O <sub>7</sub>	800	1357.2	N	(976)
	c	2016.0	-73.0 <sup>18</sup> <sub>1000</sub>	(120, 458, 733, 934, 976)
	∞	1939.1	dil.	
	1200	1942.9	N	(119, 122, 899, 976)
	1000	1943.0	dil.	(934†)
	500	1945.4	dil.	
	250	1947.7	dil.	
	166	1949.1	dil.	
	sat.	1953.3	dil.	
KOCrClO <sub>2</sub>	c	1016	19.5 <sup>666</sup>	(723)
K <sub>2</sub> Cr <sub>2</sub> O <sub>8</sub>	c	2584	-59	(458)
KCr(SO <sub>4</sub> ) <sub>2</sub>	aq.	2525	N; analogy	
KNH <sub>4</sub> CrO <sub>4</sub>	aq.	2274	+KOH	(122, 976)
	c	1263	-22 <sup>18</sup>	(899)
K <sub>2</sub> MoO <sub>4</sub>	600	1241	N	(899)
K <sub>2</sub> MoO <sub>4</sub>	aq.	1524	N	(788)
K <sub>2</sub> MoO <sub>4</sub>	aq.	1808	K <sub>2</sub> MoO <sub>4</sub> + H <sub>2</sub> O <sub>2</sub>	(788)
2KCl.UO <sub>2</sub> Cl <sub>2</sub> .2H <sub>2</sub> O	c	2764	-16	(7)
KVO <sub>2</sub>	aq.	1318	+H <sub>2</sub> O <sub>2</sub>	(821)
KVO <sub>4</sub>	aq.	1258	+H <sub>2</sub> O <sub>2</sub>	(821)
KVO <sub>4</sub>	aq.	1196	ions	
3KF.AlF <sub>3</sub>	c	3217	+HF	(32)
	aq.	3232	+HF	(32)
3KF.AlF <sub>3</sub> .3½H <sub>2</sub> O	c	4322.7	AlF <sub>3</sub> + KF	(32)
KCl.AlCl <sub>3</sub>	c	1190	252.0 <sup>15</sup> <sub>800</sub>	(32)
3KCl.AlCl <sub>3</sub>	c	2082	195.2 <sup>15</sup> <sub>1500</sub>	(32)
3KCl.2AlCl <sub>3</sub>	c	2833	469.0 <sup>15</sup> <sub>2000</sub>	(32)
KAl(SO <sub>4</sub> ) <sub>2</sub>	600	2549	+KOH	(976)
KAl(SO <sub>4</sub> ) <sub>2</sub> .12H <sub>2</sub> O	c	6026	-42.3 <sup>18</sup> <sub>1200</sub>	(389, 976)
KCl.AlCl <sub>3</sub> .6NH <sub>3</sub>	c	1984	-12.7	(32)
K <sub>2</sub> O.Al <sub>2</sub> O <sub>3</sub> .4SiO <sub>2</sub>	c	5789	+HF	(740)
	gls.	5700	+HF	(740)
K <sub>2</sub> O.Al <sub>2</sub> O <sub>3</sub> .6SiO <sub>2</sub> (adularia)	c	7579	1094 <sup>100</sup> HF	(740)
K <sub>2</sub> O.Al <sub>2</sub> O <sub>3</sub> .-6SiO <sub>2</sub> (microcline)	c	7466	+HF	(740)
	gls.	7345	1328 <sup>100</sup> HF	(740)
KCl.MgCl <sub>2</sub> (melt)	c	1091	118 <sup>18</sup>	(157.5)
KCl.MgCl <sub>2</sub> .6H <sub>2</sub> O	c	2939	-12.9 <sup>18</sup>	(157.5)
2KCl.MgCl <sub>2</sub> (melt)	c	1530	98 <sup>18</sup>	(157.5)
4KCl.MgCl <sub>2</sub>	c	2407	56 <sup>18</sup>	(157.5)
K <sub>2</sub> Mg(SO <sub>4</sub> ) <sub>2</sub>	c	2690	44 <sup>19</sup> <sub>600</sub>	(157.5, 868, 810, 976)
K <sub>2</sub> Mg(SO <sub>4</sub> ) <sub>2</sub> .2H <sub>2</sub> O	c	3303	3.8 <sup>18</sup> <sub>600</sub>	(976)
K <sub>2</sub> Mg(SO <sub>4</sub> ) <sub>2</sub> .4H <sub>2</sub> O	c	3922	disso.* &	(262)
K <sub>2</sub> Mg(SO <sub>4</sub> ) <sub>2</sub> .5H <sub>2</sub> O	c	4200	-34.5 <sup>18</sup> <sub>800</sub>	(976)
K <sub>2</sub> Mg(SO <sub>4</sub> ) <sub>2</sub> .6H <sub>2</sub> O	c	4493	-41.9 <sup>18</sup> <sub>600</sub>	(458, 810, 976)
2KCl.CaCl <sub>2</sub> (melt)	c	1684	25 <sup>14</sup>	(157.5)
K <sub>2</sub> SO <sub>4</sub> .CaSO <sub>4</sub> .H <sub>2</sub> O	c	3133	-30.2	(30)
K <sub>2</sub> SO <sub>4</sub> .5CaSO <sub>4</sub> .H <sub>2</sub> O	c	8809	3.0	(30)
KCaFeCO(CN) <sub>5</sub> .5H <sub>2</sub> O	c	1859	+O <sub>2</sub>	(823)
K <sub>2</sub> SO <sub>4</sub> .SrSO <sub>4</sub>	c	2844	-26.1 <sup>1000</sup>	(30)
KI.LiCl(melt)	c	737	14.0 <sup>18</sup>	(45)
NaK	liq.	8	368.8	(556)
NaK <sub>2</sub>	liq.	25	546.7	
NaK <sub>3</sub>	liq.	22	743	
Na <sub>2</sub> K	liq.	5	559	
KNaC <sub>2</sub> H <sub>3</sub> O <sub>4</sub>	c	1740	7.8	(56)
	aq.	1732	N	(56)
KNaC <sub>2</sub> H <sub>3</sub> O <sub>4</sub> .4H <sub>2</sub> O	c	2928	-50.8	(56, 247, 359)
3KCNS.NaCNS	c	844	-150.7	(1023)



Formula	State	Q, kj	Method	Lit.
<b>Rubidium<sup>a</sup></b>				
Rb.....	c	0	Def.	
Rb <sup>+</sup> .....	∞	256	RbCl	
Rb <sub>2</sub> O.....	c	347	335 <sup>19</sup>	(41, 853, 854)
Rb <sub>2</sub> O <sub>3</sub> .....	c	448	+H <sub>2</sub> SO <sub>4</sub>	(419)
Rb <sub>2</sub> O <sub>4</sub> .....	c	565	analogy	(419)
RbOH(β).....	c	423.5	59.7 <sup>15</sup> <sub>110</sub>	(397)
RbOH(α).....	c		Tr.; 7.1 <sup>145</sup> <sub>(β)</sub>	(815)
	100	483.9	Rb + H <sub>2</sub> O	(41, 854)
	3.18	472.9	dil.	(408)
RbOH.(H <sub>2</sub> O) <sub>0.418</sub> .....	c		32.1 <sup>15</sup> <sub>110</sub>	(397)
RbOH.H <sub>2</sub> O.....	c	754	16.1 <sup>15</sup> <sub>110</sub>	(397)
RbOH.2H <sub>2</sub> O.....	c	1058.5	-2.7 <sup>15</sup> <sub>110</sub>	(397)
RbF.....	c	557.9	24.3 <sup>15</sup> <sub>110</sub>	(411)
	400	582.2	N	(414)
RbF. $\frac{1}{2}$ H <sub>2</sub> O.....	c	661.6	15.7 <sup>15</sup> <sub>110</sub>	(413)
RbF. $\frac{1}{2}$ H <sub>2</sub> O.....	c	1014.0	-2.6 <sup>15</sup> <sub>110</sub>	(413)
RbHF <sub>2</sub> .....	c	919.4	-22.2 <sup>15</sup> <sub>110</sub>	(414)
	400	897.3	N	(414)
RbCl.....	c	439.3	-17.7 <sup>21</sup> <sub>400</sub>	(399, 493, 1073)
	400	420.7	N; analogy	
RbBr.....	c	402	-24.9 <sup>15</sup> <sub>110</sub>	(411)
	400	375	ions	
RbBr <sub>2</sub> .....	c	381	dissoc.*	(336*)
RbBrCl <sub>2</sub> .....	c	437	dissoc.*	(336*)
RbBr <sub>2</sub> Cl.....	c	421	dissoc.*	(336*)
RbI.....	c	338	-27.2 <sup>15</sup> <sub>110</sub>	(411)
	aq.	311	ions	
RbI <sub>2</sub> .....	c	285	dissoc.*	(336†)
RbICl <sub>2</sub> .....	c	421	dissoc.*	(336†)
RbIBr <sub>2</sub> .....	c	364	dissoc.*	(336†)
Rb <sub>2</sub> S.....	c	367	103	(856)
	aq.	470	N	(856)
Rb <sub>2</sub> SO <sub>4</sub> .....	c	1422.8	-27.9 <sup>18</sup> <sub>220</sub>	(399)
	440	1395.5	N	(399)
RbHSO <sub>4</sub> .....	c	1147.1	-15.6 <sup>15</sup> <sub>220</sub>	(399)
	330	1131.3	N	(399)
RbI.4SO <sub>2</sub> .....	c	1666	dissoc.*	(342*)
RbNO <sub>2</sub> (I).....	c	500.6	-36.7 <sup>21</sup> <sub>400</sub>	(493)
RbNO <sub>2</sub> (I).....	c		Tr.; 4.4 <sup>164</sup> <sub>(II)</sub>	(234)
	200	464.5	ions	
RbBr.3NH <sub>3</sub> .....	c	629	dissoc.*	(187†)
RbI.6NH <sub>3</sub> .....	c	801	dissoc.*	(187†)
Rb <sub>2</sub> CO <sub>3</sub> .....	c	1146	36.6	(402)
	aq.	1183	N	(402)
	sat.	1179.0	dil.	(405)
Rb <sub>2</sub> CO <sub>3</sub> .H <sub>2</sub> O.....	c	1457	12.0 <sup>15</sup> <sub>110</sub>	(405)
Rb <sub>2</sub> CO <sub>3</sub> . $\frac{1}{2}$ H <sub>2</sub> O.....	c	1612	-0.8 <sup>15</sup> <sub>110</sub>	(405)
Rb <sub>2</sub> CO <sub>3</sub> . $\frac{3}{2}$ H <sub>2</sub> O.....	c	2199	-15.1 <sup>15</sup> <sub>110</sub>	(405)
RbHCO <sub>3</sub> .....	c	965	-19.8 <sup>15</sup> <sub>110</sub>	(264, † 406)
	aq.	945	N	(405)
4Rb <sub>2</sub> CO <sub>3</sub> .CO <sub>2</sub> .5 $\frac{1}{2}$ H <sub>2</sub> O.....	c	6758	-32.3	(407)
RbCNS.....	c	238	-60	analogy
	aq.	179	ions	
2RbCNS.SO <sub>2</sub> .....	c	571	dissoc.*	(342*)
2RbCl.ThCl <sub>4</sub> .....	c	2401	81	(268)
2RbCl.ThCl <sub>4</sub> .9H <sub>2</sub> O.....	c	5046	11	(268)
4RbCl.ThCl <sub>4</sub> .....	c	3208	115	(268)
2RbCl.CuCl <sub>2</sub> .....	c	1116	-12.8 <sup>18</sup> <sub>800</sub>	(226)
2RbCl.CuCl <sub>2</sub> .2H <sub>2</sub> O.....	c	1720	-44.5 <sup>18</sup> <sub>800</sub>	(226)

**Cesium<sup>b</sup>**

Cs.....	c	0	Def.	
Cs <sup>+</sup> .....	∞	260	CsCl	
Cs <sub>2</sub> O.....	c	344	348 <sup>18</sup> <sub>600</sub>	(44, 853, 854)

<sup>a</sup> RbCl + KCl; heat of solution, (959). Rb<sub>2</sub>SO<sub>4</sub>.CuSO<sub>4</sub>.6H<sub>2</sub>O, heat of dissociation (262). Rb<sub>2</sub>SO<sub>4</sub>, double salts with CdSO<sub>4</sub>, MnSO<sub>4</sub>, CoSO<sub>4</sub>, ZnSO<sub>4</sub>, NiSO<sub>4</sub>, MgSO<sub>4</sub>, heat of dissociation of hydrate (262).

<sup>b</sup> CsCNS. $\frac{1}{2}$ SO<sub>2</sub>, heat of dissociation (342). Cs<sub>2</sub>SO<sub>4</sub>.CuSO<sub>4</sub>.6H<sub>2</sub>O, heat of dissociation (261, 262). Cs<sub>2</sub>SO<sub>4</sub>.X.SO<sub>4</sub>.6H<sub>2</sub>O, X = Cd, Mn, Co, Zn, Ni, Mg; heats of dissociation (262). CsAuCl<sub>4</sub>, heat of dissociation (780.5).

Formula	State	Q, kj	Method	Lit.
<b>Cesium.—(Continued)</b>				
Cs <sub>2</sub> O <sub>4</sub> .....	c	576	138 <sup>15</sup> <sub>H<sub>2</sub>SO<sub>4</sub>(2400)</sub>	(409)
CsOH(β).....	c	419.6	68.7 <sup>15</sup> <sub>110</sub>	(42, 297)
CsOH(α).....	c		Tr.; 7.4 <sup>223</sup> <sub>(β)</sub>	(815)
	400	488.9	Cs + H <sub>2</sub> O	(44, 854)
	sat.	476	dil.	(408)
CsOH.H <sub>2</sub> O.....	c	756.4	18.0 <sup>15</sup> <sub>110</sub>	(397)
CsF.....	c	552.3	35.0 <sup>15</sup> <sub>110</sub>	(401)
	400	587.5	ions	
CsF. $\frac{1}{2}$ H <sub>2</sub> O.....	c	760.5	17.7 <sup>15</sup> <sub>110</sub>	(413)
CsF. $\frac{1}{2}$ H <sub>2</sub> O.....	c	1012.6	4.1 <sup>15</sup> <sub>110</sub>	(413)
CsHF <sub>2</sub> .....	c	918.1	-15.6	(414)
	aq.	902.5	N	(414)
CsCl(β).....	c	445.6	-19.2 <sup>19</sup> <sub>220</sub>	(42, 299, 493)
CsCl(α).....	c		Tr.; 5.6 <sub>(β)</sub>	(1073)
	gas	243	→ c*	(266)
	400	425.89	N	(42)
	200	426.15	dil.	(867°)
	100	426.62	dil.	
	50	427.40	dil.	
CsBr.....	c	407.9	-28.2 <sup>15</sup> <sub>110</sub>	(399)
	aq.	380	ions	
CsBr <sub>2</sub> .....	c	388	dissoc.*	(336*)
CsBrCl <sub>2</sub> .....	c	442	dissoc.*	(336*)
CsBr <sub>2</sub> Cl.....	c	425	dissoc.*	(336*)
CsI.....	c	350.5	-34.5 <sup>15</sup> <sub>110</sub>	(399)
	aq.	317	ions	
CsI <sub>2</sub> .....	c	300	dissoc.*	(336*)
CsICl <sub>2</sub> .....	c	428	dissoc.*	(336*)
CsIBr <sub>2</sub> .....	c	372	dissoc.*	(336*)
CsI <sub>2</sub> Br.....	c	357	dissoc.*	(336*)
Cs <sub>2</sub> S.....	c	366	114	(856)
	aq.	480	N	(856)
Cs <sub>2</sub> SO <sub>4</sub> .....	c	1427	-20.8 <sup>15</sup> <sub>220</sub>	(399)
	440	1406	N	(399)
CsHSO <sub>4</sub> .....	c	1152	-15.6 <sup>15</sup> <sub>220</sub>	(399)
	220	1137	N	(399)
CsI.4SO <sub>2</sub> .....	c	1693	dissoc.*	(342*)
CsNO <sub>2</sub> (II).....	c	509.7	-40.2 <sup>20</sup> <sub>400</sub>	(493)
CsNO <sub>2</sub> (I).....	c		Tr.; 3.5 <sup>153</sup> <sub>(II)</sub>	(234*)
	400	469.50	ions	
	200	471.08	dil.	(867°)
	100	472.22	dil.	
	60	473.49	dil.	
Cs <sub>2</sub> CO <sub>3</sub> .....	c	1143.1	49.5 <sup>15</sup> <sub>220</sub>	(402)
	aq.	1193.6	N	(402)
	sat.	1192.8	dil.	(402)
Cs <sub>2</sub> CO <sub>3</sub> . $\frac{3}{2}$ H <sub>2</sub> O.....	c	2209.3	-15.1 <sup>15</sup> <sub>220</sub>	(405)
CsHCO <sub>3</sub> .....	c	968	-18 <sup>15</sup> <sub>220</sub>	(262, * 406)
	aq.	950	N	(406)
6Cs <sub>2</sub> CO <sub>3</sub> .CO <sub>2</sub> .11H <sub>2</sub> O.....	c	10 760	-34.4	(407)
6Cs <sub>2</sub> CO <sub>3</sub> .CO <sub>2</sub> .18 $\frac{1}{2}$ H <sub>2</sub> O.....	c	12 770	-108.0	(407)
Cs <sub>2</sub> ThCl <sub>6</sub> .....	c	2357	136	(268)
Cs <sub>2</sub> ThCl <sub>6</sub> .8H <sub>2</sub> O.....	c	4770	10	(268)
Cs <sub>4</sub> ThCl <sub>6</sub> .....	c	3261	83	(268)
2CsCl.CuCl <sub>2</sub> .....	c	1134	-19.7 <sup>18</sup> <sub>800</sub>	(226)
2CsCl.CuCl <sub>2</sub> .2H <sub>2</sub> O.....	c	1727	-41.0 <sup>12</sup> <sub>800</sub>	(226)
CsLiICl(melt).....	c		1.6 <sub>240</sub>	(45)
CsNaICl(melt).....	c		-38.2 <sub>240</sub>	(45)
CsKICl.....	c		-50.2 <sub>240</sub>	(45)

**LITERATURE**

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## PARTIAL AND TOTAL HEATS OF FORMATION OF AQUEOUS SOLUTIONS

F. RUSSELL BICHOWSKY

## ABBREVIATIONS AND SYMBOLS

$x_1$	Mole fraction of $H_2O$ ("solvent").
$x_2$	Mole fraction of solute.
$N$	$\frac{x_1}{x_2}$
%	Weight per cent solute.
$-H$	Total heat of formation of solute in solution, from its elements in their standard states at the same temperature (v. p. 169).
$-\bar{H}_2$	$\frac{\partial H}{\partial x_2}$
$-\bar{H}_1$	$\frac{\partial H}{\partial x_1}$

To calculate the heat of any reaction involving these solutions at constant  $T$  and  $p$ , proceed as in the case of pure substances but use partial heat of formation  $\bar{H}$ , instead of heat of formation  $H$ .

Example: To compute the heat of the following reaction at

60°C:  $NH_3 + 4H_2O$  (in solution) =  $0.4NH_3 + 3.6H_2O$  (in solution) +  $0.6NH_3$  (gas) +  $0.4H_2O$  (vapor).

From the table we find:

$$76.59 + 4 \times 28542 = 0.4 \times 78.68 + 3.6 \times 284.83 + 0.6 \times 46.566 + 0.4 \times 242.35 + H$$

Hence  $\bar{H} = 36.61$  kilojoule. For further details, v. Lewis and Randall, Thermodynamics (1923), Chapters 4, 7, and 8.

## HEAT OF NEUTRALIZATION OF STRONG ACIDS AND BASES AT 20°C

The solutions contain 1 mole per 100 mole of  $H_2O$  in each case. The values tabulated are joule/equiv., on the assumption that  $1\text{g-cal}_{20} = 4.181$  joule (Richards and Rowe, 1, 44: 684; 22).

	LiOH <sub>100</sub>		NaOH <sub>100</sub>		KOH <sub>100</sub>	
	Q	dQ/dt	Q	dQ/dt	Q	dQ/dt
HCl <sub>100</sub> .....	58 254	-231.6	58 095	-220.3	58 593	-202.4
HBr <sub>100</sub> .....	58 572		57 878		58 484	
HI <sub>100</sub> .....	58 220		57 614		58 179	
HNO <sub>3</sub> <sub>100</sub> .....	57 961	-224.1	57 852	-211.1	58 894	-188.6

## HCl

$x_2 = \text{HCl}$	$x_2$	0.3	0.2	0.1	0.05	0.02	0.01	0.005	0.0	$x_1 = H_2O$	
gas	N	2.33	4.0	9.0	19.0	49.0	99.0	199.0	$\infty$	gas	liq.
	%	46.5	33.6	18.2	9.63	4.00	2.00	1.00	0.0		
92.1579	$-H$	144.4	152.3	158.84	160.95	162.50	162.84	162.80	162.46	241.89	286.848
	$-\bar{H}_2$	126.8	140.6	154.84	158.65	161.62	162.54	162.88	162.46		
0°C	$-H_1$	294.37	289.77	287.288	286.970	286.865	286.851	286.7223	286.848		
92.1956	$-H$	144.4	152.46	159.87	162.650	164.295	164.826	165.64	165.85	241.98	286.103
	$-\bar{H}_2$	126.8	139.90	153.71	159.846	163.290	164.198	165.39	165.85		
20°C	$-H_1$	293.62	289.242	286.760	286.250	286.1222	286.1096	286.1046	286.103		
92.2332	$-H$	144.8	153.38	161.33	165.06	166.73	167.57	168.32	169.1	242.10	285.450
	$-\bar{H}_2$	126.4	139.15	154.47	161.71	165.60	166.73	167.65	169.1		
40°C	$-H_1$	293.4	289.02	286.183	285.617	285.4727	285.458	285.4538	285.450		
92.2667	$-H$	145.6	154.0	162.88	166.69	168.61	169.37	169.91	172.0	242.35	284.798
	$-\bar{H}_2$	126.0	138.9	156.10	163.13	167.40	168.45	169.07	172.0		
60°C	$-H_1$	293.0	288.55	285.551	284.986	284.8236	284.805	284.802	284.798		

H<sub>2</sub>SO<sub>4</sub>

$x_2 = H_2SO_4$	$x_2$	1.00	0.80	0.60	0.50	0.40	0.20	0.10	0.05	0.002	0.00	$x_1 = H_2O$
liq.	N	0.00	0.25	0.6667	1.00	1.50	4.00	9.00	19.0	499.00	$\infty$	liq.
	%	100.00	95.6	89.1	84.5	78.4	57.8	37.66	22.29	1.04	0	
794.581	$-H$	794.56	802.35	814.61	822.77	830.30	848.97	858.64	862.40	870.40	885.25	286.848
	$-\bar{H}_2$	794.56	794.94	796.87	802.68	812.10	832.61	847.17	860.39	867.26	885.25	
0°	$-H_1$	320.45	318.06	313.50	306.93	298.98	290.94	288.14	286.97	286.852	286.848	
794.049	$-H$	794.06	803.27	813.73	830.68	830.01	849.30	857.17	864.12	871.99	884.08	286.103
	$-\bar{H}_2$	794.06	795.40	796.57	801.97	810.89	832.52	846.21	860.52	868.43	884.08	
20°	$-H_1$	320.57	317.47	312.45	306.43	298.85	290.31	287.34	286.25	286.112	286.103	
793.518	$-H$	793.52	803.73	813.61	821.81	829.80	849.64	855.79	864.24	873.58	882.91	285.450
	$-\bar{H}_2$	793.52	795.90	796.28	801.22	809.71	832.44	845.16	860.65	869.60	882.91	
40°	$-H_1$	321.12	316.97	311.49	306.01	298.85	289.77	286.68	285.63	285.459	285.450	
792.986	$-H$	792.97	804.27	812.77	821.35	829.55	845.83	854.28	864.37	875.13	881.78	284.798
	$-\bar{H}_2$	792.97	796.36	795.99	800.51	808.50	832.35	844.24	860.77	870.73	881.78	
60°	$-H_1$	320.91	316.47	310.57	305.63	298.81	289.23	285.92	285.00	284.806	284.798	
791.919	$-H$	791.93	805.28	812.14	820.39	829.01	850.60	851.48	862.86	878.31	879.44	283.500
	$-\bar{H}_2$	791.93	797.28	795.40	799.04	806.07	832.19	842.27	861.23	873.07	879.44	
100°	$-H_1$	321.28	315.47	308.64	304.84	298.81	288.10	284.54	283.70	283.513	283.500	
789.257	$-H$	789.3	807.7	809.8	818.2	827.8	852.5	845.0	861.7	886.4	873.62	280.23
	$-\bar{H}_2$	789.3	802.3	793.9	795.6	800.2	831.6	837.4	861.7	878.9	873.62	
200°	$-H_1$	322.54	312.95	303.87	302.83	298.68	285.84	280.98	280.39	280.23	280.23	
786.596	$-H$	786.8	810.2	807.3	816.5	825.7	854.20	836.6	860.9	893.9	868.0	278.09
	$-\bar{H}_2$	786.8	801.8	792.6	791.8	793.9	831.1	832.4	862.1	884.7	868.0	
300°	$-H_1$	330.2	311.4	300.1	301.7	300.1	283.7	278.7	277.0	278.09	278.09	



NH<sub>3</sub>

x <sub>2</sub> = NH <sub>3</sub>		x <sub>2</sub>	0.5	0.4	0.3	0.2	0.1	0.05	0.02	0.01	0.00	x <sub>1</sub> = H <sub>2</sub> O	
gas	liq.	N	1	1.5	2.333	4	9	19	49	99	∞	gas	liq.
		%	48.59	38.66	28.84	19.16	9.50	4.74	1.92	0.946	0.0		
45.4951	67.337	—H	76.17	78.68	79.724	80.645	81.273	81.691	81.942	81.506	81.231	241.89	286.848
		—H <sub>2</sub>	69.89	75.38	77.218	79.306	80.608	81.356	82.905	84.96	81.231		
	0°C	—H <sub>1</sub>	293.0	289.02	288.30	287.17	286.961	286.857	286.827	286.815	286.848		
45.8676	66.039	—H	73.24	77.00	78.720	79.515	80.310	80.519	80.687	80.771	80.771	241.97	286.108
		—H <sub>2</sub>	66.12	72.82	76.17	78.092	79.682	80.310	80.645	80.771	80.771		
	20°C	—H <sub>1</sub>	293.4	289.18	287.18	286.4591	286.1708	286.1146	286.1067	286.1038	286.1038		
46.2191	64.909	—H	70.78	76.2	78.176	79.097	79.808	80.059	80.148	80.185	80.185	242.10	285.450
		—H <sub>2</sub>	62.78	71.15	75.38	77.678	79.306	79.975	80.109	80.1638	80.185		
	40°C	—H <sub>1</sub>	293.4	289.18	286.7	285.806	285.508	285.455	285.4518	285.4509	285.450		
46.5665	63.319	—H		75.38	77.548	78.469	79.138	79.306	79.348	79.389	79.431	242.35	284.798
		—H <sub>2</sub>		69.47	74.07	76.59	78.68	79.264	79.348	79.389	79.431		
	60°C	—H <sub>1</sub>			286.25	285.42	284.831	284.7997	284.797	284.797	284.797		
47.2109	60.892	—H			(76.79)	(77.42)	(77.42)	(77.42)	(77.42)	(77.84)	(77.84)	(242.90)	(284.158)
		—H <sub>2</sub>			(72.46)	(75.38)	(77.01)	(77.42)	(77.42)	(77.84)	(77.84)		
	100°C	—H <sub>1</sub>			(288.8)	(286.8)	(284.20)	(288.38)	(284.158)	(284.158)	(284.158)		

## THERMAL CONDUCTIVITY

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## THERMAL CONDUCTIVITY: GASES AND VAPORS

T. H. LABY AND E. A. NELSON

Thermal conductivity,  $k$ , is defined by the relation

$$\frac{dQ}{dt} = -k \frac{d\theta}{dz} \frac{dx dy}{dz}$$

where  $dQ/dt$  is the time rate at which heat is conducted in the direction of the temperature gradient,  $d\theta/dz$ , across a parallel slab of area  $dx \cdot dy$ .

Theory.—See (1.1, 1.2, 22.1, 22.2).

Useful Formulae.—The relation,  $k = f\eta c_v$ , exists between the thermal conductivity,  $k$ , the viscosity,  $\eta$ , and the specific heat at constant volume,  $c_v$ , where  $f$  is "constant," e.g.,  $k \propto \eta$  if the temperature varies.  $f$  depends on the number of atoms in the molecule: for diatomic gases  $f = ca. 1.75$ ; for triatomic  $ca. 1.4$ ; for monatomic  $2.5$ , which is the theoretical value for spherically symmetrical molecules (13).

Accuracy of Values of  $k$ .—The experimental determination of the thermal conductivity of gases is subject to very large error. For example, the 19 determinations of  $k$  for air deviate on the average from the weighted mean (given below) by 7 per cent. The number of observers whose observations were used in deriving the weighted means which follow is equal to the number of literature citations, excluding (8).

Units.—In all of the tables of this section the thermal conductivity,  $k$ , is expressed in kilo-erg cm<sup>-2</sup> sec<sup>-1</sup> (°C, cm<sup>-1</sup>)<sup>-1</sup>.

Conversion Factors.—1 [kilo-erg cm<sup>-2</sup> sec<sup>-1</sup> (°C, cm<sup>-1</sup>)<sup>-1</sup>] = 10<sup>-4</sup> [joule cm<sup>-2</sup> sec<sup>-1</sup> (°C, cm<sup>-1</sup>)<sup>-1</sup>] = 0.239 × 10<sup>-4</sup> [cal cm<sup>-2</sup> sec<sup>-1</sup> (°C, cm<sup>-1</sup>)<sup>-1</sup>] = 0.192 × 10<sup>-4</sup> [BTU ft.<sup>-2</sup> sec<sup>-1</sup> (°F, in.<sup>-1</sup>)<sup>-1</sup>].

See further Vol. I, p. 16.

## A-TABLE.—ELEMENTARY SUBSTANCES AND ATMOSPHERIC AIR

Formula	$t$ , °C	$k$	Lit.
A.....	0	1.58	(6, 7, 18, 26, 36)
Cl <sub>2</sub> .....	0	0.718	(7)
H <sub>2</sub> .....	0	15.9	(4, 6, 7, 8, 10, 11, 17, 22, 23, 30, 36, 38, 44); cf. (10.5, 24.5, 49)
He.....	0	13.9	(6, 7, 8, 26, 36)
Hg.....	203	0.772	(24)
N <sub>2</sub> .....	0	2.28	(6, 7, 11, 33, 36, 38)
Ne.....	0	0.444	(1, 36, 37)
O <sub>2</sub> .....	0	2.33	(6, 7, 11, 31, 33, 36, 38)
S.....			Stafford's data (29) at various temperatures appear not to be comparable with the data in this and the following tables.
Air.....	0	2.23	(2, 3, 4, 8, 9, 10, 13, 17, 18, 20, 23, 26, 29, 30, 33, 36, 38, 44, 45, 46); cf. (10.5, 24.5, 49)

## B-TABLE.—CHEMICAL COMPOUNDS

Formula	$t$ , °C	$k$	Lit.
H <sub>2</sub> O.....	100	2.17	(19)
SO <sub>2</sub> .....	0	0.768	(7)
H <sub>2</sub> S.....	0	1.20	(7)
N <sub>2</sub> O.....	0	1.44	(7, 31, 36, 38)
NO*.....	0	2.08	(7, 33, 38)



B-TABLE.—CHEMICAL COMPOUNDS.—(Continued)

Formula	<i>t</i> , °C	<i>k</i>	Lit.
NO <sub>2</sub> .....	55	4.01	(33)
NH <sub>3</sub> .....	0	2.00	(7, 22, 40, 47); cf. (4.5)
CO.....	0	2.15	(7, 16, 19, 31, 38)
CO <sub>2</sub> .....	0	1.37	(4, 6, 7, 10, 17, 23, 29, 31, 33, 36, 38, 44, 47)
CCl <sub>4</sub> .....	100	0.807	(19)
CS <sub>2</sub> .....	0	0.636	(7)

\* Observed value reduced to 0° by Sutherland's formula, using *C* = 195 from viscosity data.

C-TABLE

Formula	Name	<i>t</i> , °C	<i>k</i>	Lit.
CHCl <sub>3</sub>	Chloroform.....	0	0.608	(19)
CH <sub>2</sub> Cl <sub>2</sub>	Methylene chloride.....	0	0.615	(19)
CH <sub>3</sub> Br	Methyl bromide.....	0	0.574	(19)
CH <sub>3</sub> Cl	Methyl chloride.....	0	0.841	(19)
CH <sub>3</sub> I	Methyl iodide.....	0	0.433	(19)
CH <sub>4</sub>	Methane.....	0	2.94	(7, 31, 36, 38, 48)
CH <sub>3</sub> O	Methyl alcohol.....	0	1.32	(19)
CH <sub>3</sub> N	Methylamine.....	6.5	1.51	(14)
C <sub>2</sub> H <sub>2</sub>	Acetylene.....	0	1.73	(7)
C <sub>2</sub> H <sub>4</sub>	Ethylene.....	0	1.64	(7, 16, 31, 38)
C <sub>2</sub> H <sub>5</sub> Br	Ethyl bromide.....	4.6	0.685	(19)
C <sub>2</sub> H <sub>5</sub> Cl	Ethyl chloride.....	0	0.873	(19)
C <sub>2</sub> H <sub>5</sub> I	Ethyl iodide.....	0	0.571	(19)
C <sub>2</sub> H <sub>6</sub>	Ethane.....	0	1.80	(7, 19, 48)
C <sub>2</sub> H <sub>5</sub> O	Ethyl alcohol.....	100	1.96	(19)
C <sub>2</sub> H <sub>7</sub> N	Dimethylamine.....	6.5	1.40	(14)
C <sub>2</sub> H <sub>7</sub> N	Ethylamine.....	6.5	1.34	(14, 22)
C <sub>2</sub> H <sub>5</sub> O	Acetone.....	0	0.906	(19)
C <sub>2</sub> H <sub>5</sub> O <sub>2</sub>	Methyl acetate.....	0	0.938	(19)
C <sub>3</sub> H <sub>7</sub> N	Propylamine.....	6.5	1.19	(14)
C <sub>3</sub> H <sub>7</sub> N	Trimethylamine.....	6.5	1.30	(14)
C <sub>2</sub> H <sub>5</sub> O <sub>2</sub>	Ethyl acetate.....	100	1.52	(19)
C <sub>2</sub> H <sub>5</sub> O	Ethyl ether.....	0	1.21	(19, 22)
C <sub>2</sub> H <sub>11</sub> N	Diethylamine.....	6.5	1.20	(14)
C <sub>2</sub> H <sub>11</sub> N	Isobutylamine.....	6.5	1.18	(14)
C <sub>5</sub> H <sub>12</sub>	<i>n</i> -Pentane.....	0	1.16	(19)
C <sub>5</sub> H <sub>12</sub>	Isopentane.....	0	1.15	(19)
C <sub>5</sub> H <sub>13</sub> N	<i>n</i> -Amylamine.....	6.5	1.11	(14)
C <sub>6</sub> H <sub>6</sub>	Benzene.....	0	0.825	(19)
C <sub>6</sub> H <sub>12</sub>	<i>n</i> -Hexylene.....	0	0.962	(19)
C <sub>6</sub> H <sub>12</sub>	Cyclohexane.....	101.8	1.64	(19)
C <sub>6</sub> H <sub>14</sub>	<i>n</i> -Hexane.....	0	1.03	(19)
C <sub>3</sub> H <sub>11</sub> N	Di- <i>n</i> -propylamine.....	6.5	1.02	(14)
C <sub>3</sub> H <sub>11</sub> N	Triethylamine.....	6.5	1.06	(14)

## GAS MIXTURES

% = volume % of first named constituent. The values of *k* in italics are taken from the A-Table

A + He (34) 0°C		A + N <sub>2</sub> —(Cont'd)		O <sub>2</sub> + H <sub>2</sub> —(Cont'd)	
%	<i>k</i>	%	<i>k</i>	%	<i>k</i>
0	13.9	38.920	2.047	33.33	9.922
5.39	12.29	64.130	1.855	50.0	7.639
15.32	9.700	79.617	1.745	75.0	4.649
54.63	4.503	100	1.609	80.0	4.14
72.96	3.100			84.64	3.84
100	1.58			93.94	2.99
				96.64	2.72
				100	2.49
A + N <sub>2</sub> (36) 0°C		O <sub>2</sub> + H <sub>2</sub> (35) 22°C		N <sub>2</sub> + H <sub>2</sub> (34) 0°C	
%	<i>k</i>	%	<i>k</i>	%	<i>k</i>
0	2.366	0	16.8	57.4	6.150
21.961	2.189	5.26	15.65		
		14.29	13.45		
		25.0	11.49		

CO<sub>2</sub> + H<sub>2</sub> (36) 0°C

%	<i>k</i>	%	<i>k</i>	%	<i>k</i>
0	17.40	39.318	7.204	90.596	1.993
5.705	15.01	63.017	4.323	92.47	1.872
16.545	11.70	82.989	2.539	100	1.419

## TEMPERATURE VARIATION OF THERMAL CONDUCTIVITY OF GASES

As *k* is not a linear function of the temperature, whenever possible a Sutherland equation,

$$k_T = k_{273} \frac{273 + C}{T + C} \left( \frac{T}{273} \right)^{3/2}$$

has been fitted to the observations, where *T* is the absolute temperature, and the value of the constant *C* so obtained is used to compute

$$\alpha_0 = \frac{1}{k_{273}} \left( \frac{dk}{dT} \right)_{273}$$

and *k<sub>T</sub>/k<sub>273</sub>*. When no value of *C* is given, no Sutherland equation would fit the observations, and the directly observed values of *k<sub>i</sub>/k<sub>0</sub>* or of *k<sub>i</sub>* are given. In parentheses is given the temperature interval over which Sutherland's equation may be applied with accuracy. If *α* is required for a gas not given below, it may be calculated by using a value of *C* obtained from viscosity observations on that gas.

A-TABLE.—ELEMENTARY SUBSTANCES AND ATMOSPHERIC AIR

A (6)		Hg (24)		Air (4, 6, 19, 23, 47)	
<i>t</i> , °C	<i>k<sub>i</sub>/k<sub>0</sub></i>	<i>α</i> <sub>192.5 to 215°</sub>	<i>C</i> = 125	<i>t</i> , °C	<i>k<sub>i</sub>/k<sub>0</sub></i>
-182.4	0.366	0.0074	<i>α</i> <sub>0</sub> = 0.00298	-191.1	0.316
-78.4	0.750			-150	0.485
0	1.0			-100	0.674
+100	1.31			-50	0.844
H <sub>2</sub> (4, 6, 7, 23)		N <sub>2</sub> (6)		Ne (37)	
<i>t</i> , °C	<i>k<sub>i</sub>/k<sub>0</sub></i>	<i>α</i> <sub>191.4 to +100°</sub>	<i>C</i> = 114	<i>t</i> , °C	<i>k<sub>i</sub>/k<sub>0</sub></i>
-252.2	0.067	0.00277	<i>α</i> <sub>0</sub> = 0.00291	-191.4	0.323
-200	0.304			-150	0.494
-150	0.511			-100	0.680
-100	0.693			-50	0.848
-50	0.855			0	1.0
0	1.0			+50	1.14
+50	1.13			100	1.28
100	1.26			150	1.40
He (6, 7)		O <sub>2</sub> (6)		Ar (37)	
<i>t</i> , °C	<i>k<sub>i</sub>/k<sub>0</sub></i>	<i>α</i> <sub>191.4 to +100°</sub>	<i>C</i> = 144	<i>t</i> , °C	<i>k<sub>i</sub>/k<sub>0</sub></i>
-252.2	0.154*	0.00223	<i>α</i> <sub>0</sub> = 0.00235	-191.4	0.302
-200	0.399			-150	0.472
-150	0.593			-100	0.664
-100	0.749			-50	0.839
-50	0.882			0	1.0
0	1.0			+50	1.15
+50	1.11			100	1.29
100	1.20				

\* Obs. value; but *k<sub>i</sub>/k<sub>0</sub>* = 0.120 according to Sutherland's equation which fits observations above -252°.

\* These values of *k<sub>i</sub>/k<sub>0</sub>* calculated from the observations of Stafford (29) when plotted against *t*, give a curve of opposite curvature to that obtained from the results of other observers. Caution is necessary, therefore, in combining his observations with the others given. The values given in the table are calculated relative to the value of *k<sub>273</sub>* obtained from Sutherland's formula, using *C* = 125.







## THERMAL CONDUCTIVITY OF NON-METALLIC SOLIDS

M. S. VAN DUSEN

For industrial materials, see Vol. II, p. 312, 316; single crystals, p. 230; SiO<sub>2</sub>, p. 106. Data for other non-metallic solids, and for such of the preceding as are of special importance in the construction of scientific instruments are given in the following

table. Data for crystalline materials and for compressed powders are too scanty to permit any general conclusion to be drawn; the values tabulated are subject to considerable uncertainty. For conductivity of powders under reduced gas pressure, see Vol. II, p. 315.

## THERMAL CONDUCTIVITY OF NON-METALLIC SOLIDS

Am. = amorphous, Art. = artificial, Crys. = crystalline, Nat. = natural;  $B_{183}$  = boils at 183°C;  $d$  = density of the specimen at 20°C, not of the individual grains of a powder;  $D$  = thermal diffusivity near  $t_R$ ;  $K_t$  = thermal conductivity at  $t$ , °C;  $M_{114}$  = melts at 114°C;  $p$  = hydrostatic pressure;  $P$  [PP] = compressed [highly compressed] powder;  $t_R$  = room temperature,  $K_t = C\{1 + \alpha t(10)^{-4}\}$  if  $t$  lies within the range indicated; unless 0°C lies within the range,  $C$  is not  $K_0$ .  $K_{t,p} = K_{t,1}\{1 + bp(10)^{-4}\}$ . In the portion for inorganic solids, the "remarks" in section A apply also to the corresponding entries in section B.

Unit of  $K_t$  and  $C = 10^{-4}$  watt/(cm°C); of  $D = 1$  cm<sup>2</sup> sec<sup>-1</sup>; of  $d = 1$  g cm<sup>-3</sup>; of  $p = 1$  atm.;  $t_0$ ,  $M$ ,  $B$  and range are °C

## Pure organic solids

Formula	Substance	$t$	$K_t$	$C$	$\alpha$	Range	$C$	$\alpha$	Range	Remarks	Lit.
C <sub>2</sub> H <sub>2</sub> O <sub>4</sub>	Oxalic acid.....	0	90	90	-58	-190 to 0					(9)
C <sub>2</sub> H <sub>5</sub> O <sub>3</sub>	Glycerol.....	0	30	30	-17	-90 to +10	38	+10	-180 to -90	$d = 1.263$ ; solid*	(32)
C <sub>6</sub> H <sub>5</sub> NO <sub>2</sub>	<i>p</i> -Nitrophenol.....	0	27	27	-19	-50 to +50	25	-47	-180 to -50	$M_{114}$	(32)
C <sub>6</sub> H <sub>7</sub> N	Aniline.....	-40	28.9	24	-51	-100 to -40	18	-103	-180 to -100	$B_{183}$ ; $M_{-8}$	(32)
C <sub>7</sub> H <sub>9</sub> N	<i>p</i> -Toluidine.....	30	16							$M_{45}$	(30)
C <sub>10</sub> H <sub>8</sub>	Naphthalene.....	0	38	38	-33	-160 to +80				$M_{79}$	(9, 30, 32)
C <sub>10</sub> H <sub>8</sub> O	$\alpha$ -Naphthol.....	35	24		< 0						(30)
C <sub>10</sub> H <sub>8</sub> O	$\beta$ -Naphthol.....	35	24.6	25	-5	-170 to +100					(30, 32)
C <sub>10</sub> H <sub>9</sub> N	Naphthylamine.....	33	15		< 0					$M_{50}$	(30)
C <sub>10</sub> H <sub>14</sub> O	Thymol.....	12	15				$D = 0.00108$			$M_{13}$	(4)
C <sub>12</sub> H <sub>11</sub> N	Diphenylamine.....	0	22	22	-6.5	-180 to +30				$M_{54}$	(32)
C <sub>12</sub> H <sub>22</sub> O <sub>11</sub>	Sucrose.....	0	58	58	-45	-80 to 0					(9)
C <sub>17</sub> H <sub>15</sub> O <sub>3</sub>	$\beta$ -Naphthyl salicylate	-80	22	20	-13	-190 to 0				Crystalline	(9)
C <sub>17</sub> H <sub>15</sub> O <sub>3</sub>	$\beta$ -Naphthyl salicylate	-80	12	14	+20	-190 to -80				Amorphous	(9)

\* Probably a glass.

## PURE INORGANIC AND MISCELLANEOUS SOLIDS

## A. One temperature and effect of pressure

Substance		$t$ , °C	$K_t$	Remarks	Lit.
AgCl.....	Art.	0	109	$d = 3.06$	(16)
AgCl.....	Nat.*	0	110	$d = 7.2$	(16)
AgCl.....	PP	$t_R$	75		(50)
AgBr.....		0	103	$d = 5.9$	(16)
Al <sub>2</sub> O <sub>3</sub> .....		15	1 050		(31)
Al <sub>2</sub> O <sub>3</sub> .....	<i>P</i>	$t_R$	68	$d = 1.84$	(28)
C (Dia)†.....	Crys.	0	15 000	$D = 1.5$	(10)
C (Gr)†.....	Art.	0	15 000	$D = 1.5$	(7, 10, 18, 20, 23, 41, 45)
C.....	Am.	0	††	$D = 0.04$ to $0.4$	(3, 7, 18, 19, 20, 44, 49)
C (Gr)†.....	<i>P</i>	40	119	$d = 0.70$ ; $F \frac{1}{2}$ 20 on 40	(45)
C (Gr)†.....	<i>P</i>	40	38	$d = 0.42$ ; $F \frac{1}{2}$ 40	(45)
C (Gr)†.....	<i>P</i>	40	18	$d = 0.48$ ; $F \frac{1}{2}$ 100	(45)
C (LB)†.....	<i>P</i>	40	6.5	$d = 0.165$	(45)
C (CD)†.....	<i>P</i>	40	11.2	$d = 0.73$	(45)
CaF <sub>2</sub> .....		0	1 100		(9)
CaF <sub>2</sub> .....		-190	3 900		(9)
CaCl <sub>2</sub> ·6H <sub>2</sub> O.....		24	63		(30)
CaSO <sub>4</sub> ·2H <sub>2</sub> O.....	Art.	$t_R$	38	$d = 1.36$ ; $D = 0.0025$	(49)
CaSO <sub>4</sub> ·2H <sub>2</sub> O.....	Art.	$t_R$	74	$d = 2.13$	(19)
CaSO <sub>4</sub> ·2H <sub>2</sub> O.....	Nat.‡	$t_R$	130	$d = 2.88$ ; $D = 0.0042$	(49)
Ca <sub>3</sub> (PO <sub>4</sub> ) <sub>2</sub> .....	PP	$t_R$	41		(50)
CaCO <sub>3</sub> .....	Nat.¶	30	219	$d = 2.602$ ; $b = 1.0$	(6)
CaCO <sub>3</sub> .....	Nat.¶	75	188	$d = 2.602$ ; $b = 6.7$	(6)
CdO.....	<i>P</i>	$t_R$	68	$d = 3.39$	(28)
Co <sub>2</sub> O <sub>3</sub> .....	<i>P</i>	$t_R$	42	$d = 1.96$	(28)
Cr <sub>2</sub> O <sub>3</sub> .....	<i>P</i>	$t_R$	45	$d = 2.35$	(28)
CuO.....		15	330		(31)
CuO.....	<i>P</i>	$t_R$	102	$d = 2.19$	(28)
CuCl <sub>2</sub> .....		15	54		(31)
CuS.....		15	580		(31)
CuSO <sub>4</sub> ·5H <sub>2</sub> O.....	PP	$t_R$	82		(50)
CuSO <sub>4</sub> ·5H <sub>2</sub> O.....		15	73		(31)
FeO.....	<i>P</i>	$t_R$	56	$d = 2.24$	(28)
Fe <sub>2</sub> O <sub>3</sub> .....		15	126		(31)
Fe <sub>2</sub> O <sub>3</sub> .....	<i>P</i>	100	49		(8)
FeS.....		15	710		(31)
FeSO <sub>4</sub> ·7H <sub>2</sub> O.....		15	56		(31)
FeC <sub>2</sub> O <sub>4</sub> ···	PP	$t_R$	52		(50)
H <sub>2</sub> O (ice).....	Crys.	0	209	$d = 0.92$ ; $D = 0.011 \uparrow \uparrow$	(2, 13, 32, 35, 36, 42)
H <sub>2</sub> O (snow).....	Crys.		‡‡		(1, 22, 24, 26, 26, 38)
HgCl <sub>2</sub> .....	PP	$t_R$	61		(50)
HgBr <sub>2</sub> .....	PP	$t_R$	53		(50)
I.....		30	44		(40)
KCl.....		0	670		(9, 16)
KCl.....		-190	2 100		(9)
KI.....		0	500	$d = 1.97$	(19)



Substance	$t$ , °C	$K$	Remarks	Lit.
$K_2Cr_2(SO_4)_4 \cdot 24H_2O$	0	55		(9)
MgO	15	126		(31)
MgO	$t_R$	55	$d = 0.80$	(28, 50)
$MgSO_4 \cdot 7H_2O$	15	48		(31)
$MgCO_3$	$t_R$	43	$d = 3.0$	(52)
$MgSiO_3$	$t_R$	36		(50)
NaCl	0	670		(6, 9, 29, 31, 33, 49)
NaCl	-190	2 600		(9)
NaCl	30	368	$b = 36$	(6)
NaCl	75	316	$b = 36$	(6)
$NaClO_3$	0	112		(9)
$Na_2HPO_4 \cdot 12H_2O$	25	54		(30)
NiO	$t_R$	94	$d = 1.45$	(28)
$NiSO_4 \cdot 7H_2O$	15	48		(31)
$NiCO_3$	$t_R$	58		(50)
PbO	15	210		(31)
PbO	$t_R$	72	$d = 5.84$	(28, 52)
$Pb_2O_3$	15	210		(31)
$Pb_2O_4$	$t_R$	55	$d = 4.7$	(52)
$PbF_2$	$t_R$	40		(50)
$PbCl_2$	15	54		(31)
$PbCl_2$	$t_R$	33		(50)
$PbBr_2$	$t_R$	26		(50)
$PbI_2$	$t_R$	24		(50)
PbS	15	65		(31)
S	-190	64		(9)
S	0	21		(9, 19, 29, 30, 33, 36, 37)
S	Am.	0	20	(9)
Si	30	8 400		(27)
$SiO_2$ (glass)	0	145	v. also p. 106	(3, 9, 11)
TiCl	0	98	$d = 6.6$	(16)
TiBr	0	82	$d = 7.1$	(16)
ZnO	15	380		(31)
ZnO	$t_R$	59	$d = 2.80$	(28, 52)
$ZnSO_4 \cdot 7H_2O$	15	61		(31)
Basalt (diabasic)	30	169	$d = 2.924$ ; $b = 4.7$	(6)
Basalt (diabasic)	75	173	$d = 2.924$ ; $b = 2.2$	(6)
Canada balsam	$t_R$	11		(12, 29)
Catlinite	30	183	$d = 2.84$	(6)
Chalk	$t_R$	71	$d = 1.547$ ; $D = 0.0054$	(49)
Fibre (white)	0	29	$d = 1.22$	(30, 46)
Ivory (⊥ axis)	80	45 to 52		(17)
Ivory (   axis)	80	57		(17)
Mica	$t_R$	40 to 60		(17, 43)
Micanite	$t_R$	20 to 40		(17, 43, 48)
Paraffin	0	24	$D = 0.0024$ ; $M 50-54$	(9, 14, 28, 29, 30, 32, 33, 34, 37, 39, 47, 48, 51)
Pyrex glass	30 to 75	109	$d = 2.234$ ; $b = 4$	(6)
Rubber (hard)	0	16	$d = 1.2$ ; $D = 0.0016$	(3, 8, 9, 16, 17, 21, 29, 30, 33, 37, 46)
Rubber (soft)	$t_R$	13 to 16	>90 % pure	(17, 29, 32, 47)
Shellac	$t_R$	25		(29, 30, 32)
Talc	30	307	$d = 2.751$ ; $b = 15.7$	(6)
Vaseline	$t_R$	18		(30, 34)

## B. Variation with temperature

Substance	$C$	$\alpha$	Range, °C	Lit.
AgCl	Art.	109	-45	0 to 100 (16)
AgBr	Art.	103	-45	0 to 100 (16)
C (Dia)†	Crys.	15 000	0	-200 to +100 (16)

Substance	$C$	$\alpha$	Range, °C	Lit.
C (Gr)†	Art.	15 000	-3.3	0 to 2 000 (7, 10, 18, 29, 23, 41, 45)
C	Am.	††	>0?	0 to 600 (3, 17, 18, 19, 20, 44, 49)
C (Gr)‡	P	100	+48	40 to 100 (45)
C (Gr)‡	P	33	+40	40 to 100 (45)
C (Gr)‡	P	16	+34	40 to 100 (45)
C (LB)‡	P	6.4	+6	40 to 150 (45)
C (CD)‡	P	10.3	+23	30 to 150 (45)
CaF <sub>2</sub>		1 100	-37	-80 to +100 (9)
Fe <sub>2</sub> O <sub>3</sub>	P	39	+25	100 to 700 (5)
H <sub>2</sub> O (ice)	Crys.	209	-17	-170 to 0 (2, 13, 32, 35, 36, 42)
H <sub>2</sub> O (snow)	Crys.	§§		(1, 22, 24, 26, 36, 38)
KCl		670	-44	-180 to +100 (9, 16)
NaCl		670	-44	-80 to +100 (6, 9, 29, 31, 33, 49)
NaClO <sub>3</sub>		112	-52	-80 to 0 (9)
S	Crys.	21	-25	0 to 100 (9, 19, 29, 30, 33, 36, 37)
S	Am.	20	+10	-190 to 0 (9)
SiO <sub>2</sub> (glass)		145	+23	-250 to +100 (3, 9, 11)
TiCl		98	-43	0 to +100 (16)
Fibre (white)		29	+12	0 to 80 (30, 46)
Paraffin		24	-16	-180 to +30 (9, 14, 25, 29, 30, 32, 33, 34, 37, 39, 47, 48, 51)
Rubber (hard)		16	+6	-200 to +100 (3, 8, 9, 16, 17, 21, 29, 30, 33, 37, 46)

\* Horn silver, cerargyrite.

† Diamond. If  $t < -200^\circ\text{C}$ ,  $K$  decreases with  $t$ .

‡ (Gr) = graphite, (LB) = lampblack, (CD) = coal dust.

§ F 20 on 40 means that the powder passed a sieve of 20 meshes to the inch, but was caught by one of 40; F 40 means that it passed a sieve of 40 meshes but that no indication of the limit of fineness of the powder is given.

|| Gypsum.

¶ Limestone, nearly pure  $\text{CaCO}_3$ .

\*\* Ferrous oxalate.

†† In the range 0 to  $-30^\circ\text{C}$ .‡‡ Values of  $K_0$  and  $C$  vary from  $400 \times 10^{-4}$  to  $4000 \times 10^{-4}$  watt/(cm, °C).§§ In the range 0 to  $-30^\circ\text{C}$ ,  $K = (2.1 + 42d + 216d^2) \times 10^{-4}$  watt/(cm °C),  $D = (d^{-1} + 20 + 103d^2) \times 10^{-4}$  cm<sup>2</sup> sec.<sup>-1</sup>

||| Rock salt, clear crystalline.

¶¶ Catlinite = pipestone.

$p$	1	2 000	4 000	6 000	8 000	10 000	12 000 atm.
$K_{\infty}$	183	212	228	235	240	245	$249 \times 10^{-4}$ watt/(cm, °C)

## LITERATURE

(For a key to the periodicals see end of volume)

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## THERMAL CONDUCTIVITY OF LIQUIDS AND SOLIDS

T. BARRATT AND H. R. NETTLETON

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## STANDARD MATERIALS

The materials in the following table are suitable for standardizing, calibrating, or checking of scientific apparatus and instruments.

$K_t = K_0(1 + \alpha_0 t)$ ,  $0^\circ \leq t \leq 100^\circ\text{C}$ ;  $K_t = K_{20}[1 + \alpha_{20}(t - 20)]$ ,  $0^\circ \leq t \leq 80^\circ\text{C}$ ;  $t$  = centigrade temperature.

Unit of  $K = 1 \text{ watt}/(\text{cm } ^\circ\text{C}) = 0.2389 \text{ cal}_{15}/(\text{cm sec } ^\circ\text{C}) = 1.338 \times 10^{-3} \text{ BTU}_{59}/(\text{in. sec } ^\circ\text{F})$

	$K_0$	$\alpha_0$		$K_{20}$	$\alpha_{20}$
Ag.....	4.19	-0.00017	H <sub>2</sub> O.....	0.00587	+0.00281
Cd.....	0.933	-0.00038	C <sub>2</sub> H <sub>5</sub> OH...	0.00182	-0.00071
Pb.....	0.352	-0.00016	SiO <sub>2</sub> ; v.p. 106		

## METALS AND ALLOYS

About 75% of all measurements of the thermal conductivity of pure metals and of alloys were for the purpose of testing either Wiedemann and Franz's law (<sup>115</sup>), that the ratio of the thermal ( $K$ ) to the electrical ( $\sigma$ ) conductivity is the same for all metals, or Lorenz's law (<sup>70</sup>), that  $K/\sigma$  is proportional to the absolute temperature  $T$ . The most important papers on these subjects are (3, 6, 11, 12, 15, 19, 23, 24, 30, 33, 36, 41, 49, 50, 51, 52, 53, 54, 57, 62, 64, 65, 66, 67, 70, 73, 74, 75, 77, 79, 82, 84, 92, 94, 95, 97, 98, 102, 114, 115, 120).

On the electron theories of Riecke (<sup>92.5</sup>), Drude (<sup>22.5</sup>) and others,  $K/\sigma T = \frac{4}{3}(e_0/e)^2 = 3(k_0/e)^2$ , a quantity which is independent of the metal and of  $T$ ;  $k_0$  = Boltzmann's molecular gas constant,  $e$  = electronic charge. With the values accepted for I. C. T., this gives  $10^8 K/\sigma T = 2.23 \text{ watt-ohm-}(\text{ }^\circ\text{C})^{-1}$ . For observed values, see Table 1.

For the effects of mechanical stresses, see Table 2.

TABLE 1.—RELATION OF THERMAL ( $K$ ) TO ELECTRICAL ( $\sigma$ ) CONDUCTIVITY

Tabular values are  $A = 10^8 K/\sigma T$ ; theoretical value of  $A = 2.23 \text{ watt-ohm}/(\text{ }^\circ\text{C})^2$ , on basis of the "accepted constants" (Vol. I, p. 17).

Unit of  $A = 1 \text{ watt-ohm}/(\text{ }^\circ\text{C})^2 = 10^{16} \text{ cgs.}$

	$A_{-170}$	$A_{-100}$	$A_0$	$A_{15}$	$A_{100}$	Cr-Fe,* chrome steels		
						% Cr	$A_{30}^\dagger$	$A_{150}^\dagger$
Al.....	1.50	1.81	2.09	2.19	2.27	0	2.86	2.79
Ag.....	2.04	2.29	2.33	2.36	2.37	0.5	3.01	2.73
Au.....			2.45§		2.41§	1	2.91	2.79
C  .....			1110§		770§	2	2.79	2.75
Cd.....	2.39	2.43	2.40	2.43	2.44	3	3.14	2.80
Cu.....	1.85	2.17	2.30	2.29	2.32	5	3.24	2.75
Fe.....	3.10	2.98	2.97	2.76	2.85	8.5		2.72
Ir.....			1.77§		1.60§	10	3.26	
Mo.....			3.08§		3.17§			
Ni.....	2.92	2.59	2.59	2.40	2.44			



TABLE 1.—(Continued)

	A <sub>-170</sub>	A <sub>-100</sub>	A <sub>0</sub>	A <sub>18</sub>	A <sub>100</sub>	Cr-Fe,* chrome steels		
Pb.....	2.55	2.54	2.53	2.46	2.51			
Pd.....			2.18§		2.16§	% Cr	A <sub>30</sub> †	A <sub>30</sub> ‡
Pt.....			2.47§		2.59§	13		2.73
Rh.....			1.55§		1.33§	15	2.86	
Sn.....	2.48	2.51	2.49	2.53	2.49	17		2.74
Ta.....			2.88§		2.78§	20	3.03	
Zn.....	2.20	2.39	2.45	2.31	2.33			
Mean.....	2.34	2.41	2.41	2.41	2.38			
	(67)				(57)			

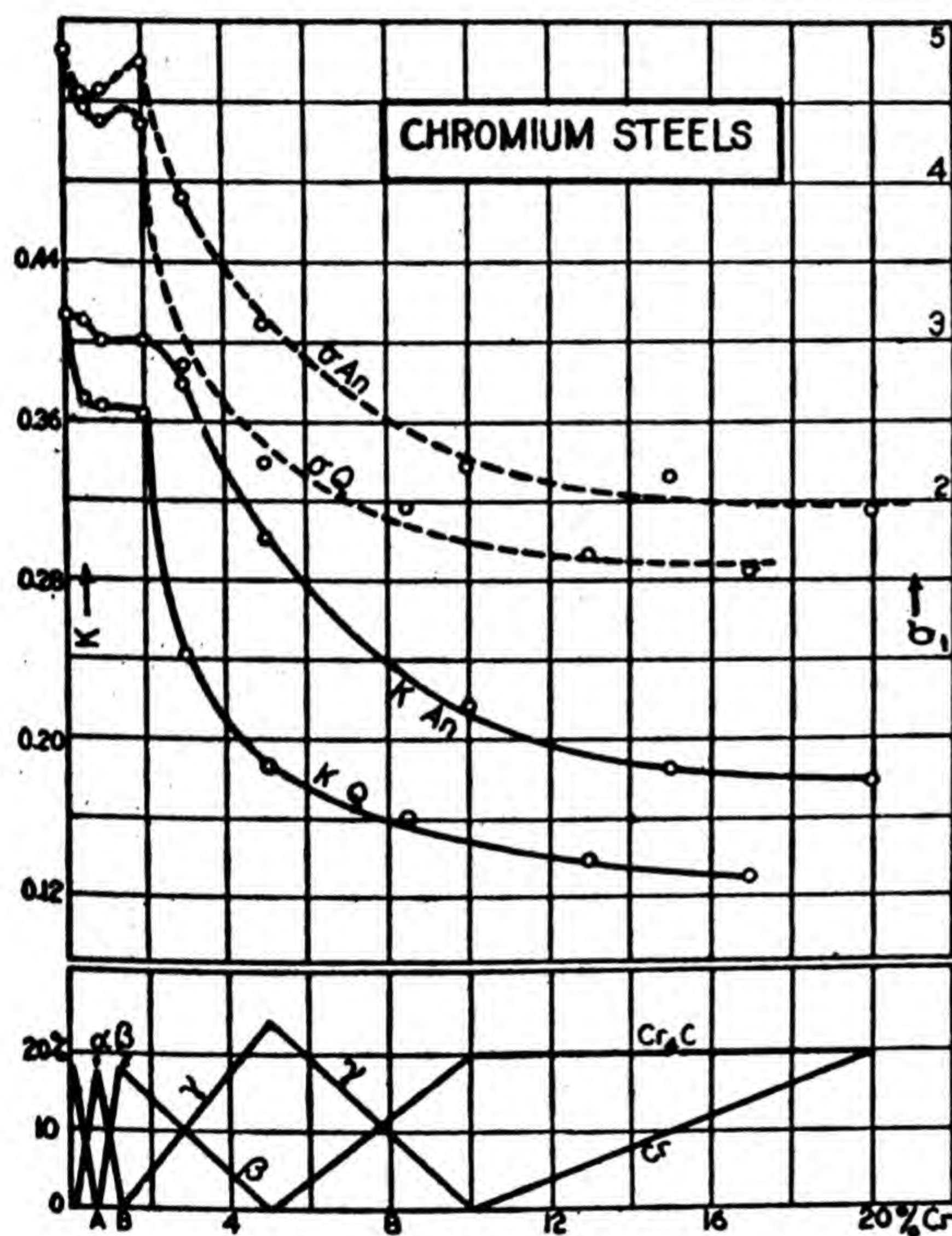
\* See Fig. 1 (75).

† Annealed 900°C.

‡ Quenched 1100°C.

§ (§).

|| Graphite (omitted from mean).

FIG. 1.—Thermal ( $K$ ) and electrical ( $\sigma$ ) conductivities of chrome steels: Variation with composition and heat treatment (75).

Unit of  $K = 1 \text{ watt/cm}^\circ\text{C}$ , of  $\sigma = 10^4 \text{ ohm}^{-1} \text{ cm}^{-1}$ . An = annealed from 900°C; Q = quenched at 1100°C. Similar curves are obtained for the coefficient of expansion and for the moduli of elasticity; their shape is intimately related to the variations in the amounts of the several phases present. (See lower section of figure; A = 0.6%, B = 1.2% of Cr;  $\alpha, \beta, \gamma$  refer to the  $\alpha, \beta, \gamma$  double carbides.)

Fe-W, tungsten steels;  $t = 30^\circ\text{C}$  (52); (see Fig. 2)

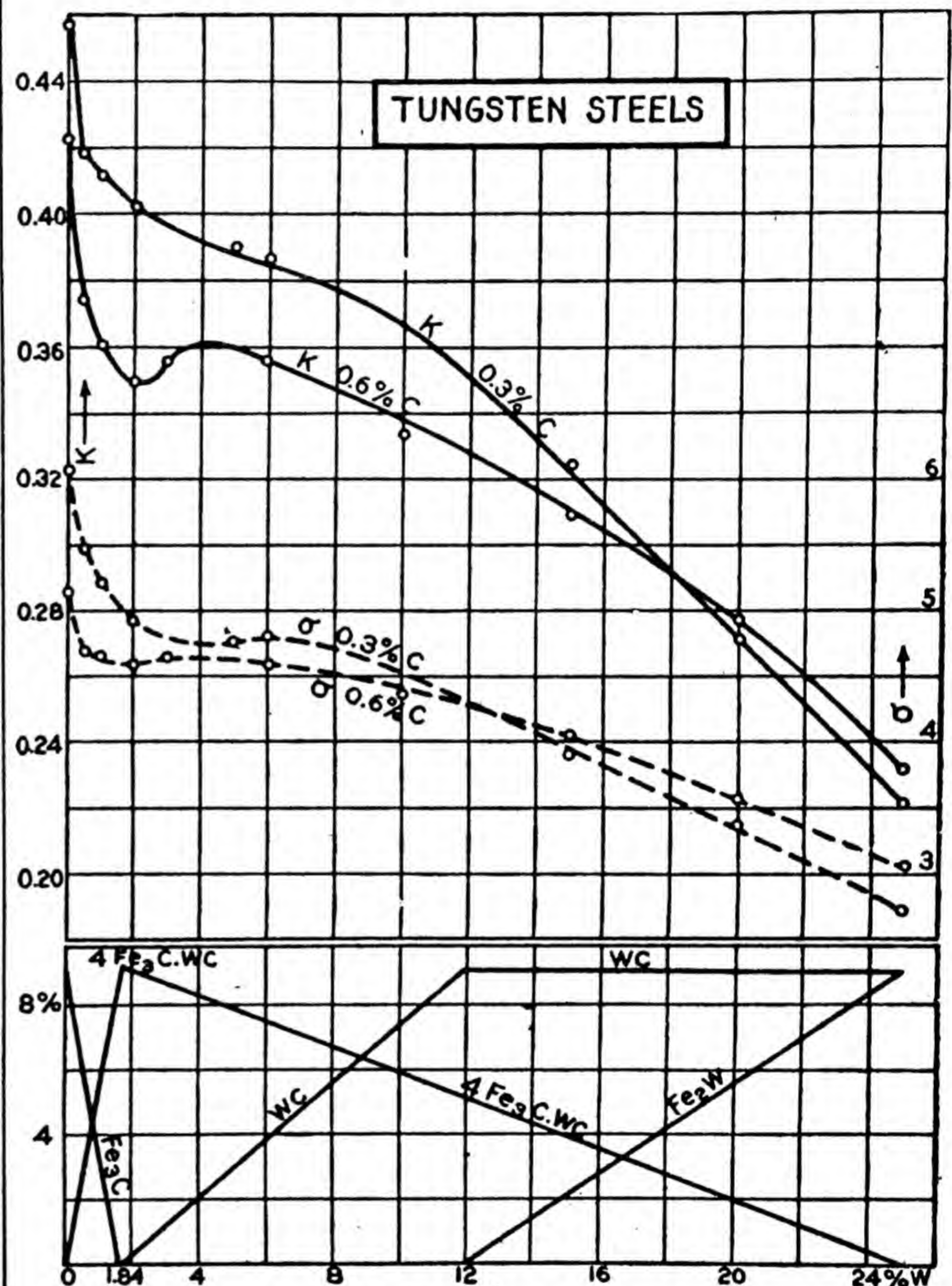
W, %	C, %	0.3	0.6	W, %	C, %	0.3	0.6	W, %	C, %	0.3	0.6
0		2.47	2.68	3		2.50		15		2.71	2.51
0.5		2.51	2.62	5		2.68		20		2.63	2.53
1		2.58	2.52	6		2.66	2.53	25		2.67	2.48
2		2.68	2.49	10		2.51					

Fe-C, steel, iron, nickel (53)

|| Manganin

Material	30°	200°	400°	600°	800°	t	A <sub>t</sub>
Carbon Steel.....						-170	5.94
C* = 0.18%.....	2.59	2.63	2.76	2.68	3.02	-100	4.16
C* = 0.64%.....	2.56	2.70	2.94	2.95	3.15	0	3.41
C* = 1.02%.....	2.77	2.76	3.11	3.27	3.25	18	3.14
C* = 1.50%.....	2.58	2.48	2.78	2.93	3.14	100	2.97
Swedish iron.....	2.85	3.03	3.08	3.00	3.28	(57, 67)	
Ni.....	2.17	2.53	2.67	2.73	2.75		

\* Krupp carbon steel, same specimen as in Table 4 "Tool or high carbon steel" No. 2.

FIG. 2.—Thermal ( $K$ ) and electrical ( $\sigma$ ) conductivities of tungsten steels: Variation with composition (52).

Unit of  $K = 1 \text{ watt/cm}^\circ\text{C}$ , of  $\sigma = 10^4 \text{ ohm}^{-1} \text{ cm}^{-1}$ . Similar curves are obtained for the moduli of elasticity; their shape is intimately connected with the variations in the amounts of the several phases present. (See lower section of figure.)

TABLE 2.—THERMAL CONDUCTIVITY ( $K$ ) OF METALS: EFFECT OF STRESSES

$K$  varies nearly linearly with hydrostatic pressure ( $P$ ) and with tensile stress ( $S$ ); under torsion,  $K$  varies approximately as the square of the twist ( $\tau$ ).

$K_0$  = conductivity of unstressed material at  $0^\circ\text{C}$ ;  $K$ ,  $K_P$ ,  $K_S$ ,  $K_\tau$  = conductivity at the same temperature unstressed, under stress  $P$ ,  $S$ ,  $\tau$ .

$K'_S$  = apparent conductivity under stress  $S$ , assuming dimensions are the same as for unstressed specimen.  $S_m, \tau_m$  = maximum values used in measurements.



TABLE 2.—(Continued)

$\delta_P \equiv 10^6(K_P - K)/KP$ ;  $\delta_S \equiv 10^6(K_S - K)/KS$ ;  $\delta'_S \equiv 10^6(K'_S - K)/KS$ ;  $A_r \equiv 100(K_r - K)/K_r^2$

Unit of  $P$  and  $S = 1 \text{ kg/cm}^2 = 9.81 \times 10^8 \text{ dyne/cm}^2 = 0.97 A_n$ ; of  $\tau = 1^\circ/\text{cm} = 0.0174 \text{ radian/cm} = 30.5^\circ/\text{ft}$ .

Material	$K_0$	$\delta_P^*$	$S_m$	$\delta_S^\dagger$	$S_m^\dagger$	$\delta'_S$	$\tau$	$A_r^\S$
Ag.....	4.19	- 3.7	790	-2.0				
Al.....	2.03		545	-3.8	463	13.8	1.84	-0.27
Bi.....	0.0837	-31						
Cd.....	0.933	+ 7.4						
Cu.....	3.88	- 7.5	1080	-2.1	463	8.0	0.74	-0.64
Cu-Zn  .....	1.05				463	6.3	1.32	-0.57
Fe.....	0.619	- 0.3	2050	-1.9			1.13	-0.59
Steel.....	0.485				1235	6.2	0.88	-2.78
Ni.....	0.586	-12	1900	+0.48	964	4.2	0.81	-0.61
Pb.....	0.352	+17.3					1.10	-0.21
Pd.....	0.674		770	-0.20				
Pt.....	0.695	- 1.6	790	-1.35				
Sb.....	0.186	-21						
Sn.....	0.657	+12					0.74	-1.83
Zn.....	1.13	+ 2.1			463	8.2	0.59	-2.01
Lit.....	(14); cf. (71)		(15); cf. (103)		(59)		(18, 68); cf. (104)	

\* Metals very pure, maximum hydrostatic pressure = 12 000 kg/cm<sup>2</sup>.

† Metals very pure, allowance made for change in dimensions due to stretching. Probable errors range from 2.4 % for Al to 23 % for Ni.

‡ Approximately 70 % of elastic limit.

§ Metals not annealed.

|| Brass.

TABLE 3.—THERMAL CONDUCTIVITY ( $K_0$ ) AT 0°C OF PURE METALS

$K_0$  = weighted mean of best determinations; "Range" = limiting values between which the true value probably lies.

Unit of  $K = 1 \text{ watt/(cm } ^\circ\text{C)} = 0.2389 \text{ cal}_{15}/(\text{cm sec } ^\circ\text{C)} = 1.338 \times 10^{-3} \text{ BTU}_{50}/(\text{in. sec } ^\circ\text{F)} = 10^7 \text{ erg/(cm sec } ^\circ\text{C)}$ .

Symbol	$K_0$	Range	Lit.
Ag	4.19	4.05 - 4.30	(35, 46, 57, 67, 99, 110); cf. (34)
Al	2.03	1.95 - 2.15	(4, 57, 58, 67, 73, 96, 117)
Au	2.96	2.85 - 3.10	(6, 57, 77); cf. (35, 99, 100)
Bi	0.0837	0.080 - 0.091	(30, 33, 57, 60, 70)
C*	0.0345	0.0325 - 0.0365	(7); cf. (28, 116)
C†	0.157	0.150 - 0.165	(7, 55); cf. (108)
Cd	0.933	0.91 - 0.95	(24, 57, 67, 70, 96, 110)
Co‡	$K_{30} = 0.692$		(51)
Cu	3.88	3.85 - 3.95	(36, 57, 62, 67, 77, 89, 93, 96)
Fe	0.619	0.57 - 0.67	(8, 12, 40, 53, 57, 67, 70, 102); cf. (9, 27, 34, 79, 97, 109)
Fe§	0.485	0.44 - 0.51	(17, 36, 53, 57, 67); cf. (34, 64)
Hg	0.0836	0.0820 - 0.0845	(11, 12, 81, 112); cf. (2, 32, 48, 69, 80, 111)
Ir	0.59	0.56 - 0.62	(6)
K	0.99		(54)
Li	0.70	0.63 - 0.77	(78)
Mg	1.55	1.50 - 1.65	(70, 73)
Mo	1.46	1.38 - 1.54	(6)
Na	1.35	1.25 - 1.45	(54); cf. (19, 90)
Ni	0.586	0.565 - 0.605	(5, 53, 57, 67); cf. (8)
Pb	0.352	0.34 - 0.36	(12, 34, 57, 62, 63, 67, 70, 72, 77, 85, 88, 96)
Pd	0.674	0.61 - 0.69	(6, 57, 99)
Pt	0.695	0.685 - 0.700	(6, 57, 77, 97)
Rh	0.894	0.87 - 0.91	(6)
Sb	0.186	0.16 - 0.21	(12, 24, 30, 70)
Se	(See Table 4)		
Sn	0.657	0.625 - 0.675	(3, 12, 34, 57, 61, 67, 70, 85); cf. (4, 63)

TABLE 3.—(Continued)

Symbol	$K_0$	Range	Lit.
Ta	0.544	0.52 - 0.57	(6)
Te	$K_{45} = 0.06$		(118)
Tl	0.39		(16)
W	1.60		(113); cf. (6)
Zn	1.13	1.06 - 1.19	(12, 57, 63, 67); cf. (34)

\* Gas carbon.

† Graphite.

‡ With 0.24 % C, 1.4 % Fe, 1.1 % Ni, 0.14 % Si.

§ Steel with ca. 1 % C.

TABLE 4.—THERMAL CONDUCTIVITY ( $K$ ) OF METALS,  $\text{Cu}_2\text{S}$ ,  $\text{Fe}_2\text{O}_3$ , AND  $\text{ZnO}$ : VARIATION WITH TEMPERATURE

For alloys of definite composition, see Table 5.

In certain cases the recorded values of  $K$  have been adjusted so as to give in each case a  $K_0$  which agrees with the weighted mean given in Table 3. These cases are indicated by an  $a$  in the column "Notes."

$s$  = solid;  $l$  = liquid;  $t'$ ,  $t''$  = limits of temperature range within which the formula of variation applies;  $\alpha$ ,  $\beta$  = coefficients defined by the equation

$$K_t = K_0[1 + 10^{-3}\alpha(t - t') + 10^{-6}\beta(t - t')^2]$$

if " $(K_0)$ " or  $K_0$  is written in the  $K_0$  column, the equation is

$$K_t = K_0[1 + 10^{-3}\alpha t + 10^{-6}\beta t^2]$$

or

$$K_t = K'_0[1 + 10^{-3}\alpha t + 10^{-6}\beta t^2]$$

depending upon whether 0°C does or does not lie within the range defined by  $t'$  and  $t''$ . In the latter case the value of  $K'_0$  is always given.

Example: For Ag,  $K_t = 4.19(1 - 0.00017t)$ , if  $0^\circ \leq t \leq 100^\circ$ ;  $K_t = K_0(1 - 0.00054t - 0.00000266t^2)$ , if  $18^\circ \geq t \geq -170^\circ$ . If  $K_0 = 4.19$  and  $t = -100^\circ\text{C}$ ,  $K_{-100} = 4.19[1 - 0.00054(-100) - 0.00000266(-100)^2] = 4.19(1 + 0.054 - 0.0266) = 4.19(1.0274) = 4.30$ . For Al, the data from (67) give  $K_t = K_0(1 + 0.000175t)$ , if  $18^\circ \geq t \geq -125^\circ$  and  $K_t = 1.98[1 - (10)^{-3}1.49(t + 125)]$ , if  $-125^\circ \geq t \geq -170^\circ$ .

Unit of  $K = 1 \text{ watt/(cm } ^\circ\text{C)} = 0.2389 \text{ cal}_{15}/(\text{cm sec } ^\circ\text{C)}$ ; of  $\alpha = (1^\circ\text{C})^{-1}$ ; of  $\beta = (1^\circ\text{C})^{-2}$ ;  $t$  = centigrade temperature.

Symbol	Notes	$t'$	$t''$	$K_1'$	$\alpha$	$\beta$	Lit.	
Ag	$a$	0	100	4.19	-0.17		(87)	
	$a$	18	-170	( $K_0$ )	-0.54	-2.66	(87)	
Al	$a$	0	100	2.03	+0.29		(87)	
	$a$	0	100	2.03	+0.184		(70)	
		18	-125	( $K_0$ )	+0.175		(87)	
	$a$	-125	-170	1.98	-1.49		(87)	
	$s, a$	0	650	2.03	-0.275	-0.34	(88)	
	$l, a$	650	800	0.90	-0.32		(88)	
		100	400	2.19	+0.137		(88)	
	$K_{-122.4} = 1.55$ ; $K_{-121.4} = 1.63$ ; $K_{-120.2} = 1.90$ ; $K_0 = 1.93$							(88)
Au	$a$	0	100	2.96	+0.04		(87)	
		0	100	( $K_0$ )	-0.07		(8)	
	$a$	$K_{-121.6} = 12.4$ ; $K_{-121.6} = 3.08$ ; $K_0 = K_{21.8}$ $= K_{100.8} = 2.96$					(77)	
Bi†	$a$	0	100	0.0837	-1.97		(87)	
		0	100	( $K_0$ )	-0.17		(70)	
	$\pm 8\% a$	$K_{-120} = 0.220$ ; $K_{-78} = 0.0945$ ; $K_{100} = 0.080$					(30, 33); cf. (72)	
	$s, a$	$K_{100} = 0.0770$ ; $K_{200} = 0.0756$ ; $K_{300} = 0.0775$					(88)	
	$l, a$	$K_{200} = 0.176$ ; $K_{400} = 0.159$ ; $K_{600} = 0.157$ ; $K_{800} = 0.156$					(88)	
		$A \uparrow = 25$ ; $K_{-123} = 0.266$ ; $K_0 = 0.113$					(28)	
		$A \uparrow = 0.017$ ; $K_{-123} = 0.098$ ; $K_0 = 0.068$					(28)	
		$K_{-120} = 0.209$ ; $K_0 = 0.0812$ ; $K_{100} = 0.0507$					(30)	
C‡	(Except graphite)							
	(1) $a$	0	100	0.0345	+1.5		(7)	
	(2)	30	150	0.00111	+2.3		(108)	
	(3)	1427	1827	0.084	+0.12		(119)	
	(4)	30	3500	mean $K = 0.068$			(48)	
	(5)	$K_{100} = 0.059$ ; $K_{200} = 0.063$ ; $K_{300} = 0.059$ ; $K_{400} = 0.046$ ; $K_{500} = 0.050$ ; $K_{600} = 0.0071$					(48)	
	(6)	$K_{200} = 0.372$ ; $K_{425} = 0.520$ ; $K_{120} = 0.540$ ; $K_{700} = 0.574$ ; $K_{1000} = 0.602$					(47)	



TABLE 4.—(Continued)

Symbol	Notes	t'	t''	K'	$\alpha$	$\beta$	Lit.	
Cl	(Graphite)							
	(1) a	0	100	0.157	+0.33		(7)	
	(2)	0	555	(K <sub>0</sub> )	-2.36	+24.2	(55)	
	(3)	50	100	0.441	+1.2		(100)	
	(4)	K <sub>100</sub> = 1.92; K <sub>200</sub> = 1.50; K <sub>300</sub> = 1.32; K <sub>400</sub> = 1.18; K <sub>500</sub> = 1.11; K <sub>600</sub> = 1.03; K <sub>700</sub> = 0.0071						(45)
	(5)	K <sub>245</sub> = 1.41; K <sub>325</sub> = 1.36; K <sub>410</sub> = 1.28; K <sub>507</sub> = 1.22; K <sub>700</sub> = 1.17; K <sub>1000</sub> = 1.05						(47)
	(6)	30	2830	mean K = 0.68			(47)	
	(7)	40	100	0.0119	+4.8		(100)	
	(8)	40	100	0.0386	+4.0		(100)	
	(9)	40	100	0.00183	+3.4		(100)	
Cd	a	0	100	0.933	-0.38		(57)	
		-170	+18	(K <sub>0</sub> )	-0.564		(57)	
	s, a	0	320	0.933	+1.2		(16)	
	l, a	320	440	0.451	+2.8		(16)	
	K <sub>-252.7</sub> = 2.35; K <sub>-251.0</sub> = 2.00; K <sub>-251.5</sub> = 1.81; K <sub>-250.7</sub> = 1.67; K <sub>-154.1</sub> = 1.03						(96)	
	a	0	100	3.88	-0.12		(57)	
	a	0	100	3.88	-0.26		(57)	
	a	-125	-170	4.18	-2.4		(57)	
		18	-125	(K <sub>0</sub> )	-0.31	+2.5	(57)	
		76	362	(K <sub>0</sub> )	-0.09		(52)	
Cu		100	600	3.78	-0.13		(95)	
	a	K <sub>-252.4</sub> = 17.45; K <sub>-251.1</sub> = 13.0; K <sub>-154.5</sub> = 4.72; K <sub>-77.1</sub> = 3.97						(77, 96)
	(1)	K <sub>-252.7</sub> = 127.1; K <sub>-252.5</sub> = 124.6; K <sub>-252.0</sub> = 120.5; K <sub>-250</sub> = 8.16; K <sub>-150.1</sub> = 5.94						(96)
	(2)	K <sub>+145</sub> = 4.37; K <sub>154</sub> = 4.05; K <sub>225</sub> = 3.90; K <sub>325</sub> = 3.78; K <sub>500</sub> = 3.59; K <sub>700</sub> = 3.43; K <sub>1000</sub> = 3.26						(47)
	(3)	An, K <sub>100</sub> = 3.77; D, K <sub>100</sub> = 3.68; C, K <sub>100</sub> = 3.22						(117)
	(4)	157		3.18			(117)	
	(5)	An, K <sub>175</sub> = 2.09; D, K <sub>154</sub> = 2.18						(117)
	(6)	0.63 % P, K <sub>100</sub> = 1.05; 1.98 % P, K <sub>100</sub> = 0.523						(89); cf. (26)
		16	555	0.00444	+4.06		(55)	
	Cu-Fe	Wrought iron, C $\leq 0.1$ %; v. also (27, 29)						
		0	100	(K <sub>0</sub> )	-0.14		(57)	
		0	100	(K <sub>0</sub> )	-0.65		(57)	
		0	100	(K <sub>0</sub> )	-0.23		(70)	
		28	58	(K <sub>0</sub> )	-0.3		(40)	
a**		-50	-170	0.623	-1.16	-8.26	(57)	
a**		18	-50	(K <sub>0</sub> )	-0.136		(57)	
††		K <sub>100</sub> = 0.561; K <sub>150</sub> = 0.545; K <sub>200</sub> = 0.515; K <sub>300</sub> = 0.486; K <sub>400</sub> = 0.444; K <sub>500</sub> = 0.402; K <sub>600</sub> = 0.364; K <sub>700</sub> = 0.352; K <sub>800</sub> = 0.322; K <sub>1000</sub> = 0.326						(52)
Cast iron, †† C $\geq 3$ %; v. also (9, 43)								
1		K <sub>100</sub> = 0.32; K <sub>150</sub> = 0.43; K <sub>200</sub> = 0.60; K <sub>300</sub> = 0.67; K <sub>400</sub> = 0.80; K <sub>500</sub> = 0.86						(42)
2	K <sub>114</sub> = 0.448						(38)	
3	K <sub>110</sub> = 0.436						(38)	
4	20	75	(K <sub>0</sub> )	-1.0	(K <sub>0</sub> ' = 0.643)	(42)		
5	K <sub>14</sub> = 0.479; K <sub>100</sub> = 0.466						(17)	
Mild steel	Mild steel, †† C = 0.1 % ca.:							
	1	0	-170	0.485	+0.15		(57)	
	2	K <sub>17</sub> = 0.555; K <sub>100</sub> = 0.544						(39)
	3	K <sub>100</sub> = 0.916; K <sub>114</sub> = 0.846; K <sub>150</sub> = 0.771; K <sub>175</sub> = 0.800; K <sub>700</sub> = 0.754; K <sub>1000</sub> = 0.745						(47); cf. (52)
	Tool or high carbon steels, †† C = 1 % ca.:							
	1	0	100	(K <sub>0</sub> )	-0.09		(57); cf. (24)	
	2	30	K <sub>1</sub> = 0.559 - 0.135b - 0.0812c		K <sub>2</sub> = 0.509 - 0.0833b - 0.0774c		(102)	
			K = 0.537 - 0.130b - 0.129c				(102)	
	3	40	L, 0.425		0.60	Unv.	(100); cf. (37, 57)	
		40	T, 0.0062		2.5	Unv.	(100); cf. (37, 57)	
	20	T, 0.0197		1.0	Asp.	(100); cf. (37, 57)		
	20	T, 0.0057		1.9	Var.	(100); cf. (37, 57)		
4 (a)	85	T, 0.0164		1.0		(100)		
(b)	85	T, 0.0125		5.3		(100)		
(c)	85	T, 0.0094		1.2		(100)		
(d)	85	T, 0.0106		6.0		(100)		

TABLE 4.—(Continued)

Symbol	Notes	$t'$	$t''$	$K'$	$\alpha$	$\beta$	Lit.
FeO <sub>2</sub> ††		150	720	0.00523	+1.93		(13)
		720	1050	0.0109	+1.53		(13)
Hg	a	0	100	0.0836	0		(11, 12, 52); cf. (32)
	s	-44	-193	0.28	-5		(32)
	s	$K_{-207.5} = 1.67$ ; $K_{-252.5} = 1.13$					(86)
Ir	a	0	100	0.59	-0.51		(6)
K	a	0	60	0.99	-1.34		(54)
Mg	a	0	100	1.55	0		(70)
		$K_{100} = 1.39$ ; $K_{200} = 1.35$ ; $K_{300} = 1.30$ ; $K_{400} = 1.30$ ; $K_{500} = 1.33$					(95)
Mo	a	0	100	1.46	-0.45		(6)
Na	a	0	90	1.35	-1.23		(54)
Ni	a	0	100	0.586	-0.31		(57); cf. (1, 38)
	a	+18	-170	( $K_0$ )	+0.504		(57)
	a	$K_0 = K_{100} = 0.586$ ; $K_{200} = 0.578$ ; $K_{300} = 0.555$ ; $K_{400} = 0.524$ ; $K_{500} = 0.550$ ; $K_{600} = 0.572$ ; $K_{700} = 0.590$ ; $K_{800} = 0.617$ ; $K_{1000} = 0.625$					(52)
		$K_{100} = 0.608$ ; $K_{200} = 0.575$ ; $K_{300} = K_{400} = K_{500} = 0.537$ ; $K_{600} = 0.565$ ; $K_{700} = 0.590$					(95)
Pb	a	0	100	0.352	-0.16		(57)
		90	210	( $K_0$ )	-0.17		(62)
	s, a	0	325	0.352	-0.40		(65); cf. (55)
	l, a	325	600	0.165	-0.20		(65); cf. (55)
	a	0	-75	0.352	-0.24		(57)
	a	-75	-170	0.357	-0.99		(57)
		$K_{-252.5} = 0.577$ ; $K_{-250} = 0.508$ ; $K_{-154} = 0.414$					(72, 77, 95)
Pd	a	0	100	0.674	+0.68		(57)
		0	100	( $K_0$ )	-0.08		(6)
Pt	a	0	100	0.695	+0.53		(57)
		0	100	( $K_0$ )	+1.8		(6)
	a	$K_{-252.4} = 3.62$ ; $K_{-151.7} = 0.758$ ; $K_0 = 0.695$ ; $K_{21.1} = 0.697$ ; $K_{100.7} = 0.702$					(77)
Rh	a	0	100	0.894	-1.0		(6)
Sb	a	0	100	0.186	-1.4		(70)
		$K_{-153} = 0.2025$ ; $K_0 = 0.1716$ (A*** = 0.0141)					(25)
		$K_{-153} = 0.4519$ ; $K_0 = 0.2452$ (A*** = 14.3)					(25)
	a	$K_{-100} = 0.367$ ; $K_{-50} = 0.217$ ; $K_0 = 0.186$ ; $K_{100} = 0.179$					(31); cf. (24)
Se		K changed by illumination, but effect is very small. (See p. 230.)					
Sn	a	0	100	0.657	-0.8		(57)
	a	+18	-100	( $K_0$ )	-1.0		(57)
	a	-100	-170	0.723	-1.54		(57)
	s, a	0	232	0.657	-0.41		(16)
	l, a	232	500	0.369	-0.66		(16)
	s, a	0	232	0.657	-0.47		(65)
	l, a	232	500	0.342	-0.20		(65)
Ta	a	0	100	0.544	-0.10		(6)
		1427	1827	0.73	+0.34		(119)
Tl	s	$K_{50} = 0.392$ ; $K_{100} = 0.405$ ; $K_{150} = 0.389$ ; $K_{200} = 0.445$					(16)
	l	350		0.247			(16)
W†††	1	0	100	( $K_0$ )	-0.10		(6)
	2	$K_{127} = 1.01$ ; $K_{147} = 1.07$ ; $K_{167} = 1.12$ ; $K_{187} = 1.17$ ; $K_{207} = 1.21$ ; $K_{227} = 1.25$ ; $K_{247} = 1.29$					(120); cf. (66)
	3	$K_{177} = (0.84)$ ; $K_{127} = 0.99$ ; $K_{177} = 1.11$ ; $K_{227} = 1.21$ ; $K_{257} = (1.27)$					(39)
Zn	a	0	100	1.13	-0.15		(57)
	a	+18	-125	( $K_0$ )	-0.081		(57)
		-125	-170	1.13	-0.74		(57)
	s, a	0	420	1.13	-0.10	-0.83	(55)
	l, a	420	600	0.587	-0.13		(55)
		$K_{100} = 1.07$ ; $K_{200} = 1.02$ ; $K_{300} = 0.99$					(95)
ZnO		?		0.00695			(116)

\* Commercial aluminium.

† See also p. 231, Table 15. A = mean area of crystals; unit = 1 mm<sup>2</sup>.‡ Bi powder, compressed 5000 kg/cm<sup>2</sup>.§ (1) = Gas carbon,  $d = 1.42$  g/cm<sup>3</sup>. (2) = Lampblack. (3) = Untreated lamp filaments. (4) = Carbon "Idler." (5) = Petroleum coke. (6) = Carbon electrodes for furnaces, K measured under operating conditions.|| (1) = Graphite,  $d = 2.11$ . (3) = Solid graphite,  $d = 1.58$ . (4) = Acheson graphite. (5) = Graphite electrodes, K measured under operating conditions.



tions. (6) = Graphite "Idler." (7), (8), (9) = Powdered graphite, compressed 3 kg/cm<sup>2</sup>;  $d = 0.70, 0.42$ , and  $0.48$ , respectively; the powder passed sieves of 8, 16, and 40 meshes per cm, respectively.

¶ (1) = Natural crystal. (2) = Cu electrode,  $K$  measured under operating conditions. (3) = Electrolytic Cu; An = annealed, Cu = 99.98%; D = hard-drawn, Cu = 99.97%; C = cast, Cu = 99.98%. (4) = Lake Cu, cast, Cu = 99.76%. (5) Contains Cu, 99.44%; Ni, 0.20%; Fe, 0.036%; As, 0.231%; An = annealed; D = hard-drawn. (6) Cu containing P, as indicated. Additional references for Cu: (4, 8, 11, 20, 34, 35, 41, 42, 76, 91).

\*\* Contains 99.4% Fe, 0.14% Mn, 0.13% Ni, 0.1% C.

†† Swedish charcoal iron.

‡‡ (1) 3.5% C, 0.64% Mn, 2.2% Si; Soft gray. (2) Very brittle,  $d = 7.06$ ; Southern. (3) 3.64% C, 1.33% Si, 0.59% P; Gun-iron. (4) 3.5% C, 0.52% Mn, 1.40% Si, 0.55% P, 0.052% Cu, 0.106% S. (5) 3% C, 1% Mn, 3% Si, 1% P.

§§ 2. Open hearth, boiler plate; 0.1% C, 0.35% P. 3. Cold-rolled mild steel; electrodes.

|| 2. Krupp carbon steels; 12 kinds: C, 0.14% to 1.5%; Si, 0.05% to 0.34%; Mn, 0.27% to 0.67%; P, 0.01% to 0.051%; S, 0.014% to 0.044%; Cu, 0.05% to 0.13%.  $f$  = forged;  $a$  = annealed in *vacuo*, 900°C, 1 hr;  $q$  = quenched in oil from 900°C. In the equations in the table,  $b$  = sum of atomic percentages of Mn and Si;  $c$  = % C.

$t =$	30	100	200	300	400	500	600	700	800	850
C, %	1000 $K_1$ (53)									
0.18	452	452	452	427	402	372	360	364	305	309
0.44	339	339	339	335	326	305	297	259	305	309
0.64	439	439	435	410	410	337	355	339	251	259
0.80	423	435	423	423	402	389	352	393	297	293
1.02	431	423	431	414	414	402	381	414	309	318
1.30	360	360	368	368	360	339	318	414	326	322
1.50	360	360	364	355	347	326	309	872	272	272

For relation of  $K$  to electrical conductivity, see Table 1, Fe-C.

3. Steel stampings, stacked.  $L$  = along the laminations,  $T$  = across them; by inserting suitable material between the sheets,  $K$  can be increased some 3 or 4 times. "W. A." silicon steel gave results similar to those tabulated. Unv. = unvarnished; Asp. = coated with asphalt paint; Var. = varnished.

4. Sheet steel, sheets stacked and under pressure of 8.7 kg/cm<sup>2</sup>; about 3% of total volume = air space and 9.5% = varnish. (a) = ordinary sheet steel; (b) = same, enamelled; (c) = silicon sheet steel, oxide coated; (d) = same, enamelled.  $T$  denotes that  $K$  is measured across the laminations.

¶¶ Compressed powder.

\*\*\*  $A$  = Mean area of crystals; unit = 1 mm<sup>2</sup>.

††† 1. "Pladuram." 3. Aged W filaments, values in parentheses are extrapolated.

TABLE 5.—THERMAL CONDUCTIVITY ( $K$ ) OF ALLOYS AND AMALGAMS  
For certain commercial metals (Fe, Cu, etc.), see Table 4.

The alloys are arranged in alphabetical order of the symbols of their constituents.

A superior  $a$  prefixed to a conductivity ( $^aK$ ,  $\approx 0.208$ ) denotes that the observations have been adjusted to accord with the conductivities of the pure constituents as given in Table 3.

$d$  = density;  $l$  = liquid;  $s$  = solid;  $t'$ ,  $t''$  indicate the range over which the temperature formula applies;  $\alpha$ ,  $\beta$  are the coefficients in the equation

$$K_t = K_{t'} [1 + (10)^{-\alpha}(t - t') + (10)^{-\beta}(t - t')^2]$$

unless " $(K_0)$ " is written in the  $K_{t'}$  column, then  $K_t = K_0 [1 + (10)^{-\alpha}at + (10)^{-\beta}bt^2]$ ,  $\alpha_0$  always refers to the equation  $K_t = K_0 [1 + (10)^{-\alpha}at]$ ;  $\sigma$  = electrical volume resistivity. Unless otherwise indicated, the composition is expressed in grams of constituent per 100 g of alloy. All temperatures are centigrade.

Unit of  $K = 1$  watt/(cm °C) = 0.2389 cal<sub>15</sub>/(cm sec °C) =  $1.338 \times 10^{-3}$  BTU<sub>55</sub>/(in. sec °F); of  $d = 1$  g/cm<sup>3</sup>.

#### Ag-Au (100)

Au		$^aK_0$	$^aK_{100}$	Au		$^aK_0$	$^aK_{100}$
At. %	Wt. %			At. %	Wt. %		
0	0	4.19	4.12	50.9	65.4	0.64	0.92
5.0	8.8	2.33	2.53	55.1	69.2	0.76	0.94
9.7	16.4	1.60	1.69	59.9	73.2	0.71	0.96
14.5	23.6		1.43	70.3	81.3	0.80	0.98
20.0	31.4	0.99	1.28	81.3	88.8	0.98	1.26
30.2	44.2	0.87	1.04	89.3	93.8	1.38	1.62
39.7	52.3	0.78	1.00	95.1	97.3	1.86	2.15
45.4	60.3	0.76	0.97	100.0	100.0	2.96	2.95

#### Ag-Cd (100)

Cd		$^aK_0$	$^aK_{100}$
At. %	Wt. %		
0	0	4.19	4.12
5.7	5.9	1.65	1.92
11.6	12.0	1.05	1.32
19.9	20.5	0.80	0.96
27.7	31.4	0.73	0.92

#### Ag-Cu (105)

Cu	$K_{105}$	Cu	$K_{105}$
0	4.05	50	3.12
5	3.52	55	3.14
15	3.43	60	2.75
25	3.30	70	2.63
35	3.19	80	2.67
40	3.11	90	3.02
45	3.13	95	3.25
47	3.11	100	3.82

#### Ag-Pb (105)

Pb	$K_{105}$
0	4.05
10	0.988
20	0.744
30	0.577
40	0.561
50	0.489
60	0.439
70	0.395
80	0.381
90	0.352
100	0.347

#### Ag-Pd (99)

Pd	$^aK_{105}$	Pd	$^aK_{105}$
0	4.17	60	0.27
10	1.44	70	0.32
20	0.85	80	0.37
30	0.58	90	0.48
40	0.46	100	0.67
50	0.32		

#### Ag-Pt (99)

Pt	$^aK_{105}$
0	4.17
10	1.00
25	0.39
30	0.31
33	0.30

#### Ag-Sn (105)

Sn	$K_{105}$	Sn	$K_{105}$
0	4.05	60	0.611
10	0.297	70	0.611
20	0.196	80	0.611
27.5	0.393	90	0.602
40	0.490	100	0.632
50	0.577		

#### Ag-Sn (46)

Sn = 4%		$K_{105}$	
$t = 53.0$		75.5	
$K = 0.55$		0.57	

#### Ag-Tl (46)

2.73% Tl		4.76% Tl	
$t$	$K$	$t$	$K$
23.5	1.58	48.5	1.10
37.5	1.62	88.0	1.15

#### Ag-Zn (100)

Zn		$^aK_0$	$^aK_{100}$
At. %	Wt. %		
0	0	4.19	4.12
4.0	2.5	2.14	2.28
8.8	5.6	1.60	1.81
11.9	7.6	1.49	1.72
16.3	10.5	1.43	1.65

#### Al-Cd-Cu-Mg-Mn-Zn (22) "Dow-metal" alloys, sand cast

	$a$	$b$	$c$
Al.....	8.0	2.0	8.3
Cd.....	1.0	2.0	1.0
Cu.....	1.0	3.8	2.0
Mg.....	90.0	92.0	88.0
Mn.....		0.2	0.2
Zn.....			0.5
$K_{100}$ .....	0.753	1.22	0.737

#### Al-Cr-Cu-Fe-Si

$t = 30^\circ$  (73)

Cr	Cu	Fe	Si	$d$
0.87	1.78	0.92	0.38%	2.74
Annealed 30 min at 450°, $K = 1.09$ ; chill cast, $K = 1.05$ .				

#### Al-Cu

Aluminium-bronze (3)

Cu = 90%;  $K = 0.753$ ;  $t = ?$

Al-Cu (105); see also Al-Mg

Cu	$K_{105}$	Cu	$K_{105}$
0	2.11	60	0.753
10	1.61	70	0.744
20	1.45	80	0.293
30	1.30	90	0.316
50	1.06	100	3.85

#### Al-Cu-Fe-Mg-Mn-Ni-Si-Sn-Zn (73)

$t = 30^\circ$ ;  $K_1$ , chill cast;  $K_2$ , annealed 30 min at 450°C.

$K_0$  is approximately same for all these alloys.

Alloy	Cu	Si	Fe	Mn
$a$		0.137	0.509	
$b$		11.88	0.80	
$c$	12.21	0.30	0.62	
$d$	12.17	0.22	0.64	0.98
$e$	8.42	0.27	0.70	0.71
$f$	4.32	0.38	0.87	0.55*
$g$	8.07	0.38	0.63	Zn
$h$	2.70	0.39	0.57	12.02
$i$	2.57	0.37	0.57	20.32

Alloy	$d$	$K_1$	$K_2$
$a$	2.70	1.86	2.00
$b$	2.67	1.31	1.78
$c$	2.93	1.24	1.48
$d$	2.92	0.93	1.33
$e$	2.81	1.02	1.35
$f$	2.78	1.22	1.52
$g$	2.83	1.39	1.67
$h$	2.94	1.32	1.33
$i$	3.20	1.07	1.08

\* Also, Mg = 0.42; Zeppelin alloy.



## Al-Cu-Fe-Mn-Si-Zn (117)

	a	b	c	d	e
Al	99.49	91.17	92.05	91.44	91.33
Cu	0.07	7.61	6.78	7.30	8.04
Fe	0.30	0.56	0.58	0.59	0.63
Mn		0.35	0.36	0.41	
Si	0.30	0.31	0.23	0.23	
Zn	0.07	Tr.	Tr.	0.03	
t	136°	163°	173°	172°	154°
K	1.97	1.38	1.42	1.38	1.46

a = No. 1 commercial hard drawn aluminium.

b = All pig Al, sand cast. c = Scrap Al, sand cast.

d = 50% pig Al, 50% scrap Al, sand cast.

e = All pig Al, chill cast.

## Al-Cu-Fe-Mn-Sn-Zn (21)

Manganese bronze; high tensile brass

Al	Cu	Fe	Mn	Sn	Zn
0.95	57.14	1.84	2.33	0.26	37.48
t'	t''	K <sub>0</sub>	α	β	
0	400	0.670	0.72	0.16	

## Al-Cu-Sn

Aluminium-bronze (117)

Al	Cu	Sn	t	K
9.09	89.87	0.47	240	0.73

## Al-Mg (22)

"Dow-metal" alloy, sand cast

Mg	K <sub>100</sub>	Mg	K <sub>100</sub>
85	0.611	94	0.841
88	0.670	96	0.942
90	0.720	98	1.11
92	0.774	100	1.57

## Al-Mg (105)

	a	b	c	d	e	f*
Al	0	4.12	10.12	99.88	97.52	95
Mg	99.95	95.82	89.82	0	0	0.5
Cu				0.027	0.48	4
Fe	0.028	0.028	0.028	0.030	0.66	
Mn					1.07	6.5
Si	0.014	0.019	0.023	0.059	0.27	
K <sub>100</sub>	1.50	0.665	0.485	2.09	1.69	1.85

\* Composition approximately as given.

## Al-Mg-Mn (22)

"Dow-metal" alloy; sand cast

Al	Mg	Mn	K <sub>100</sub>
5.8	94.0	0.2	0.845

## Al-Sb (105)

Sb	K <sub>100</sub>	Sb	K <sub>100</sub>
0	2.11	60	0.477
10	1.84	70	0.418
20	1.59	80	0.218
30	1.41	90	0.243
40	1.00	100	0.201
50	0.807		

## Al-Sn (105)

Sn	K <sub>100</sub>	Sn	K <sub>100</sub>
0	2.11	70	1.14
10	1.86	80	0.950
30	1.73	90	0.811
50	1.39	100	0.628
60	1.25		

## Al-Zn (105)

Zn	K <sub>100</sub>
0	2.11
10	1.62
20	1.36
30	1.32
60	1.19
100	1.16

## Au-Cd (100)

At. %	Wt. %	*K <sub>0</sub>	*K <sub>100</sub>
0	0	2.96	2.95
5.4	3.1	1.24	1.48
8.7	5.1	0.96	1.17
17.2	10.6	0.72	0.80

## Au-Cu (100)

At. %	Wt. %	*K <sub>0</sub>	*K <sub>100</sub>
0	0	2.96	2.95
9.5	3.3	1.10	1.35
20.0	7.4	0.68	0.80
30.2	12.2	0.58	0.69
68.1	30.7	0.59	0.63
79.3	55.3	0.69	0.72
89.6	73.5	1.04	1.28
100	100	3.88	3.83

## Au-Pd

t = 25°C (99)

Pd	*K	Pd	*K	Pd	*K
0	2.96	40	0.38	80	0.41
10	0.92	50	0.35	90	0.52
20	0.56	60	0.35	100	0.67
30	0.42	70	0.39		

## Au-Pt

t = 25°C (99)

Pt	*K
0	2.96
10	0.69
20	0.38
30	0.28
40	0.24

## Au-Zn (99)

At. %	Wt. %	*K <sub>0</sub>	*K <sub>100</sub>
0	0	2.96	2.95
4.9	3.0	1.18	1.33
10.1	6.5	0.67	0.81

## Bi-Cd (105)

Cd	K <sub>100</sub>
0	0.079
10	0.129
20	0.163
30	0.209
40	0.251
50	0.339
60	0.393
70	0.489
80	0.597
90	0.720
100	0.941

## Bi-Cd-Pb-Sn

	Bi	Cd	Pb	Sn	t	K <sub>t</sub>
a*	48	13	26	13	7	0.133
b†	50	11	25	14	0	0.184

\* a = Wood's alloy, melts 70°C (110); b = Lipowitz's alloy, melts 65°C (87).

† a<sub>0</sub> = 0.268 if 18° ≥ t ≥ -170°C.

## Bi-Pb

t = ?; Volume % (98)

Pb	K
0	0.0778
0.43	0.0787
0.76	0.0725
1.53	0.0540
1.65	0.0498
2.69	0.0490
3.53	0.0540
8.53	0.0765
42.30	0.122
74.77	0.196

## Bi-Pb.—(Continued)

Pb	K
94.41	0.310
100	0.335

Pb = 46% (weight) (16)

t'	t''	K <sub>t'</sub>	α
0	130	0.100	-0.48 s
130	300	0.90	+1.2 l

## Bi-Pb-Sn

Rose's metal (114)

Bi	Pb	Sn	t	K <sub>t</sub>
50	25	25	12.5	0.167

## Bi-Sb

(a) Cast metal (30)

Values of 1000 \*K

% Sb	-190°	-77°	0°	100°
0	214	89	83.7	80
9	55	49	54	58
11	41	36	44	62
13	45	42	52	66
20	46	44	53	71
50	60	61	68	80
70	71	76	81	97
100	367	218	186	179

(b) Pressed powders (30)

Value of 1000 K, pressure = 5000 kg/cm<sup>2</sup>

% Sb	-190°	-80°	0°	100°
0	208		81	51
5	58		60	67
7			49	57
11	160		90	65
13	93		88	81
100		137	121	105

## Bi-Sn (117)

t = 12.5 (98)

Sn	K
33.3	0.096
50.0	0.234
66.7	0.423
100	0.636
0*	0.0795
0.46*	0.0585
0.95*	0.0527

## Bi-Sn.—(Continued)

Sn*	K
2.87	0.0460
9.74	0.0527
23.87	0.117
50.10	0.209
75.07	0.368
95.73	0.561
100	0.627

\* Volume %; t = ?



## Cd-Hg (46)

Hg	<i>t</i>	<i>K</i>
5.14	56	0.84
5.14	95	0.83
10	64	0.72
10	82.5	0.71

## Cd-Sb (24)

Values of  $\alpha K$ 

Sb	-190°	-70°	0°
0	0.113	0.933	0.933
33.3	0.139	0.118	0.112
50	0.055	0.276	0.0226
51.7*	0.386	0.214	0.0138
66.7	0.272	0.179	0.0136
100	0.290	0.218	0.186

\* Equimolecular.

## Cd-Sn (105)

Sn	<i>K<sub>105</sub></i>
0	0.942
10	0.875
20	0.837
30	0.783
40	0.754
50	0.699
60	0.653
70	0.645
80	0.594
90	0.557
95	0.536
100	0.628

## Cd-Tl (105)

Tl	<i>K<sub>105</sub></i>
0	0.970
10	0.865
20	0.799
30	0.754
40	0.703
50	0.662
60	0.582
70	0.535
80	0.494
90	0.444
100	0.440

## Cd-Zn (105)

Zn	<i>K<sub>105</sub></i>
0	0.941
10	0.954
20	0.966
30	0.996
40	1.02
60	1.04
70	1.07
80	1.09
95	1.13
100	1.16

## Co-Cr (105)

Cr	<i>K<sub>105</sub></i>
0	0.490
10	0.142
30	0.130
40	0.105

## Co-Fe (51)

Cobalt iron

Wt. % of impurities in "Fe"  
= 0.09 C, 0.288 Cu, 0.31 Mn,  
0.03 P, 0.026 S, 0.11 Si; in "Co"  
= 0.24 C, 1.4 Fe, 1.1 Ni, 0.14  
Si.

Co	<i>K<sub>105</sub></i>
0	0.457
5	0.402
10	0.395
15	0.409
20	0.438
30	0.503
40	0.599
50	0.712
70	0.721
80	0.512
90	0.402
100	0.692

Similar curves found for other  
properties.

## Cr-Fe

Chromium steels (75)  
Annealed from 900°C

Cr	<i>K</i>
0	0.418
0.5	0.416
1	0.402
2	0.400
3	0.374
5	0.305
10	0.218
15	0.186
20	0.179
Quenched at 1100°C	
0	0.410
0.5	0.371
1	0.369
2	0.364
3	0.291
5	0.186
8.5	0.162
13	0.140
17	0.130

See Fig. 1.

## Cr-Ni (105)

Ni	<i>K<sub>105</sub></i>
50	0.117
60	0.126
70	0.109
90	0.197
100	0.586

## Cu-As-Ni-Sb (21)

Arsenical copper; Pb, Sn = 0  
Cu | As | Ni | Sb | *K<sub>0</sub>*  
99.530 | 0.389 | 0.022 | 0.003 | 2.13  
 $\alpha_0 = 0.088$  if  $0^\circ \leq t \leq 400^\circ$ .

## Cu-Fe-Pb-Sn-Zn (21)

*a* = Phosphor bronze, *b* = Admiralty gun-metal, *c* = Ordinary  
gun-metal, *d* = 70:30 Brass, *e* = Monel metal, *f* = White bearing  
metal.

	Cu	Fe	Pb	Sn	Zn
<i>a</i> *	87.82	0.17	Tr.	11.28	Tr.
<i>b</i>	87.24	0.21	0.35	10.02	2.18
<i>c</i>	85.05	0.21	0.98	8.72	5.04
<i>d</i>	70.29	0.31	0.34	0.35	28.71
<i>e</i> †	29.07	2.68	0.84	67.05	
<i>f</i> ‡	4.00	0.14	0.12		87.80

\* *a* contains 0.35 P. † *e* contains 0.30 Si. ‡ *f* contains 7.73 Sb.

	<i>t'</i>	<i>t''</i>	<i>K<sub>0</sub></i>	$\alpha$	$\beta$
<i>a</i>	0	400	0.481	1.2	0
<i>b</i>	0	400	0.544	0.98	-0.48
<i>c</i>	0	400	0.682	0.49	-0.15
<i>d</i>	0	400	0.963	0.87	-0.87
<i>e</i>	0	400	0.239	2.3	-2.8
<i>f</i>	0	200	0.259	3.1	0

## Cu-Mn-Ni, Manganin

Cu = 84, Mn = 12, Ni = 4%

<i>t'</i>	<i>t''</i>	<i>K<sub>t'</sub></i>	$\alpha$	$\beta$	Lit.
0	100	0.208*	+2.7		(57, 67)
0	-170	*0.208	+2.65	+4.5	(67)

\*  $K_0 = 0.208 \pm 0.005$ .

## Cu-Mg (22)

"Dow-metal" alloy; sand cast

Mg	<i>K<sub>200</sub></i>
96.0	0.325

## Cu-Mn (105)

Mn	<i>K<sub>105</sub></i>
0	3.84
10	0.272
20	0.171
30	0.134
40	0.130
60	0.113
80	0.105

## Cu-Ni (105)

Ni	<i>K<sub>105</sub></i>
10	0.389
30	0.242
40	0.226
50	0.226
60	0.226
70	0.289
80	0.306
100	0.586

## Cu-Ni

Eureka, Constantan, etc.

Ni	<i>t</i>	<i>K<sub>t</sub></i>	Lit.
3.94	38.5	0.89	(46)
3.94	56.5	0.91	(46)
17.3	53.5	0.37	(46)
17.3	75	0.39	(46)
46	18	0.202	(36)

## Ni (100)

At. %	Wt. %	* <i>K<sub>0</sub></i>	* <i>K<sub>100</sub></i>
0	0	3.88	3.83
5.4	5.0	1.02	1.20
10.8	10.0	0.61	0.87
21.4	20.0	0.36	0.46
41.9*	40.0	0.22	0.29
62.8	60.9	0.24	0.28
82.8	81.6	0.27	0.27
100	100	0.59	0.57

\* Eureka, Constantan;  $K_0 = 0.218$   
 $\pm 0.005$  (6, 8, 57); cf. (3); if  $0^\circ < t <$   
 $100^\circ$ ,  $\alpha_0 = +2.4$  (57),  $\alpha_0 = +0.7$  (6).

## Cu-Ni-Sn-Zn

"Rotguss" (57)

Cu	Ni	Sn	Zn
85.7	0.58	6.39	7.15
<i>t'</i>	<i>t''</i>	<i>K<sub>t'</sub></i>	$\alpha$
0	100	0.572	2.4

## Cu-Ni-Zn

German silver (67)

Cu = 62, Ni = 15, Zn = 22

<i>t'</i>	<i>t''</i>	<i>K<sub>t'</sub></i>	$\alpha$	$\beta$
0	100	0.239*	2.7	
18	-170	(* <i>K<sub>0</sub></i> )	1.8	1.95
0	-170	0.243†	2.7	4.5

\*  $K_0 = 0.239 \pm 0.015$  (67, 70, 115);  
cf. (34, 79, 111),  $\alpha_0 = 2.7$  (70).

† Platinoid, approximately same  
composition as German silver (67).

## Cu-Pb-Sb-Sn-Zn

"S. A. E. bearing alloys" (117)

	Cu	Pb	Sn	Sb
<i>a</i>	3.58	0.19	92.49	3.74
<i>b</i>	5.16	0.12	86.92	7.9
<i>c</i>	7.07	63.94		28.84
<i>d</i> *	79.04	9.55	10.83	

\* Also 0.30 % P.



**Cu-Pb-Sb-Sn-Zn.—(Cont'd)**

	Cu	Pb	Sn	Zn
e	84.93	5.01	5.14	4.92
f	86.60	0.04	10.55	2.81
g	85.29	8.26	5.56	0.89

	$K_{75}$	$t$	$K_i$
a	0.385	245	0.456
b	0.260	232	0.962
c	0.318	247	0.585
		230	0.741

**Cu-Sn, 5% Sn (46)**  
 $K_{45} = 0.77$ ;  $K_{51.5} = 0.83$

**Cu-Zn (100)**

At. %	Zn	Wt. %	$K_0$	$K_{100}$
0	0	0	3.88	3.83
7.1	7.3	2.11	2.29	
14.0	14.3	1.55	1.70	
27.3	27.8	1.29	1.45	
32.4	33.0	1.21	1.39	

% Zn (46)	$t$	$K_i$
3.1	41.5	2.74
3.1	73	2.76
5	38	2.13
5	75.5	2.09

% Zn (114)	$K_{18}$
11	1.14
13	1.25
18	1.30
32	1.08

Zn = 18%;  $A$  = mean area of crystals, unit = 1 mm<sup>2</sup> (25)

$A$	$K_{100}$	$K_0$
0.6	0.660	1.270
11	0.650	1.295

**Brass, Zn = 30%**

$t'$	$t''$	$K_{t'}$	$\alpha$	Lit.
0	100	1.05*	+1.5	(70)
0	-75	1.05	+1.47	(67)
-75	-170	0.94	+2.34	(67)

Yellow brass,  $K_0 = 0.855$  (70)  
 Red brass,  $K_0 = 1.03$  (70)

\*  $K_0 = 1.05 \pm 0.05$  (12, 26, 67, 70, 114); cf. (4, 24).

**Nickel steel (Krupp) (58)**

Ni = 30.4, Mn = 0.84, Cu = 0.26, Si = 0.14% (weight)

Heat treatment	$K_{25}$
Forged.....	0.121*
Annealed: 700°, 3 hr.....	0.119
Cooled:†	
-26°, 2 hr and -29°, 1 hr.....	0.120
-70°, 7 hr; -76°, 4 hr; -78°, 2 hr.....	0.120
-165°, 3 hr and -185°, 1 hr.....	0.124

\*  $K_0 = 0.116$ ;  $26^\circ \leq t \leq 71.5^\circ$ ,  $\alpha_0 = 1.78$ .

† Cooled for successive and consecutive periods to temperatures below those indicated; e.g., in fourth case the specimen was cooled below -70°C for 7 hr, below -76°C for 4 hr, and below -78°C for 2 hr, a total of 13 hr.

**Fe-Mn**

Manganese steels (74); cf. (98)

Wt. % of other substances in "Mn" = 1.90 Al, 0.07 C, 0.24 Fe, 0.46 Si; in "Fe" = 0.206 C, 0.114 Mn, 0.05 P, 0.04 S, 0.06 Si. Points of inflection near "Mn" = 1%, they exist also in curves representing other properties of these steels.

% "Mn"	$K_{30}$
0.11	0.544
0.31	0.468
0.6	0.422
0.8	0.399
1.1	0.412
1.6	0.356
2.0	0.316
3.0	0.260
5.0	0.184
7.9	0.155
8.8	0.147
9.8	0.148

**Fe-Ni (56); cf. (3)**

Nickel-iron, Invar, etc.

% Ni	$K_{65}$
0	0.597*
1	0.445
2	0.422
5	0.352
10	0.289
15	0.220
20	0.209
25	0.138
30	0.118
35†	0.110
45	0.146
75	0.289
100	0.586*

\* (57).

† Invar (Fe<sub>3</sub>Ni) contains about 35% Ni. Other properties also have maximum or minimum at Ni = 30 to 40%.

**Nickel steels (50)**

Alloys of low carbon steel and commercial nickel. Wt. % of impurities of steel = 0.09 C, 0.288 Cu, 0.31 Mn, 0.03 P, 0.26 S, 0.11 Si; of Ni = 0.29 C, 4.2 Cu, 1.25 Fe, 0.35 Mn, 0.17 S, 0.15 Si.

"Ni,"	1000 $K_{30}$	
Wt. %	$A^*$	$C^\dagger$
0	410	410
5	320	302
10	258	255
15	218	214
20	175	192
23	171	188
25	130	192
30	83	188
31.5	78	157
33	81	134
35.5	81	
40	86	
60	151	
80	236	
90	304	
100	349	

\* Annealed from 900°C.

† Precooled to -190°C.

**Ferro-nickel (3)**

Ni = 25, C = 0.27% (weight);  
 $K_i = 0.181$ ,  $t = ?$

**Fe-W**

Tungsten steel, (52); cf. Fig. 2

% C =	0.3	0.6	0.6
% W	$A^*$	$A^*$	$Q^\dagger$
0	457	422	
0.5	419	374	
1	411	360	343
2	402	350	
3		356	280
5	390		
6	387	356	238
10		332	
15	324	309	
20	270	276	182
25	221	231	167

\* Annealed from 900°C.

† Quenched at 1100°C.

**Ir-Pt (6)**

% Pt	$K_{17}$	$K_{100}$
0	0.590	0.565
80	0.176	0.176
85	0.234	0.247
90	0.310	0.314
100	0.690	0.711

**K-Na (54)**

Equi-atomic mixture

	$K_i$
-15°	0.296 s
-10	0.292 s
+5	0.229 l
20	0.243 l
30	0.249 l
40	0.257 l

**Mn-Ni (105)**

Ni	$K_{60}$
10	0.092
30	0.105
40	0.096
50	0.092
70	0.155
80	0.176
90	0.310
100	0.585

**Pb-Sb (105)**

Sb	$K_{64}$
0	0.347
10	0.263
20	0.230
30	0.218
40	0.213
50	0.202
60	0.202
70	0.197
80	0.188
90	0.202
100	0.202

**Pb-Sb**

Pb = 87, Sb = 13 (16)

$t'$	$t''$	$K_{t'}$	$\alpha$
0	248	0.268	+0.25 s
248	380	0.130	+3.66 l

**Pb-Sn (105)**

Sn	$K_{64}$
0	0.348
10	0.360
20	0.372
30	0.385
40	0.414
50	0.465
60	0.489
80	0.544
100	0.632

**Pb-Sn**

Pb = 38, Sn = 62 (16)

$t'$	$t''$	$K_{t'}$	$\alpha$
0	180	0.506	-0.56 s
180	420	0.209	+1.67 l

**Pb-Tl (105)**

Tl	$K_{63}$
0	0.347
10	0.284
20	0.251
30	0.226
40	0.201
50	0.201
60	0.226
70	0.259
80	0.322
90	0.376
94	0.402
96	0.364
98	0.385
100	0.440



Pd-Pt (99)	
Pt	$K_{25}$
	0.67
10	0.56
20	0.44
30	0.40
40	0.38
50	0.37
60	0.34
70	0.36
80	0.42
90	0.43
100	0.70

Pt-Rh (6)		
Rh	$K_{17}$	$K_{100}$
0	0.690	0.711
10	0.302	0.306

Sb-Sn (105)	
Sn	$K_{57}$
0	0.201
10	0.188
20	0.176
30	0.197
40	0.213
50	0.268
60	0.306
70	0.352
80	0.398
100	0.628

Sn-Zn, $t = ?$ (98)			
Zn, Vol. %		$K_7$	
0		1.045	
29.81		0.933	
46.17		0.886	
63.05		0.779	
76.66		0.745	
87.22		0.674	
91.07		0.657	
100		0.628	
Sn = 92, Zn = 8 (16)			
$t'$	$t''$	$K_{t'}$	$\alpha$
0	200	0.590	+0.425 s
200	440	0.230	+2.5 l

Ti-Sn (105)	
Sn	$K_{63}$
0	0.439
10	0.301
20	0.255
30	0.259
40	0.289
46.6	0.330
50	0.372
53.8	0.385
60	0.418
70	0.436
80	0.486
90	0.557
100	0.632

## LITERATURE

(For a key to the periodicals see end of volume)

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## NON-METALLIC LIQUIDS

For glasses, see p. 229 and Vol. II, p. 315

The data pertaining to the thermal conductivity ( $K$ ) of liquids are of such a character that it is very difficult to determine from them the correct value of  $K$ , and its temperature coefficient for any liquid. The data for water are the best; for the temperature coefficients of other liquids we rely almost exclusively upon a single observer (4). For only 16 liquids (Table 10-I, p. 227) is it possible either to set useful limits between which  $K$  probably lies, or to determine a reliable value for the temperature coefficient of  $K$ . Having decided upon the values for these liquids the data for other liquids which have been determined relatively to these are adjusted accordingly. Similarly, in estimating a value of  $K$  for a liquid which has been studied by a single observer, his data are modified in accordance with the way in which his data for liquids which had been studied by others departed from what seemed to be the appropriate values. The grade of the observations, or the degree of confidence with which the data here given should be accepted is indicated qualitatively by the letters A, B, C, D. A denotes a pronounced consensus of opinion; B that the value is supported by at least one strong observer; and D, that no great confidence should be placed in the value.

Several expressions relating  $K$  to other properties of the liquid have been proposed. Some, such as  $K < c\eta$ , are inequalities which seem to be too pronounced to be of practical value (15). An equality, which was early proposed, is  $\frac{K}{dc} \left( \frac{M}{d} \right)^{1/2} = \text{constant}$ , where  $c$  = specific heat,  $d$  = density,  $M$  = molecular weight. In the absence of reliable data for  $K$  and  $c$ , it is not known whether the relation is valid (1, 14, 34, 35). A third relation, involving (v) the velocity of sound and  $e_n$  (= translational energy of a molecule of ideal gas at 1°K) is  $K = 2c_p v / \delta^2$ , where  $\delta$  = mean distance between centers of adjacent molecules. Taking  $\delta = (m/d)^{1/2}$ , where  $m$  = mass of one molecule, results approximating closely to those observed are obtained, see Table 6.



TABLE 6.—COMPARISON OF OBSERVED ( $K$ ) WITH COMPUTED ( $K_c$ ) CONDUCTIVITY (4)

$$K_c = 2e_0v(d/m)^{3/2}$$

Unit of  $v = 10^8$  cm/sec; of  $(d/m)^{3/2} = 10^{14}$  cm<sup>-2</sup>; of  $K, K_c = 10^{-6}$  watt/(cm °C);  $t = 30^\circ\text{C}$ .

Formula	Substance	$v$	$(d/m)^{3/2}$	$K_c$	$K$
H <sub>2</sub> O	Water.....	1.50	10.4	630	601
CS <sub>2</sub>	Carbon disulfide.....	1.18	4.61	219	159
CH <sub>3</sub> O	Methyl alcohol.....	1.13	6.00	274	211
C <sub>2</sub> H <sub>5</sub> Br	Ethyl bromide.....	0.90	3.97	145	120
C <sub>2</sub> H <sub>5</sub> I	Ethyl iodide.....	0.78	3.81	121	111
C <sub>2</sub> H <sub>5</sub> O	Ethyl alcohol.....	1.14	4.74	218	180
C <sub>3</sub> H <sub>6</sub> O	Acetone.....	1.14	4.00	185	179
C <sub>3</sub> H <sub>7</sub> O	Propyl alcohol*	1.24	3.94	197	154
C <sub>4</sub> H <sub>10</sub> O	Butyl alcohol*	1.05	3.49	149	167
C <sub>4</sub> H <sub>10</sub> O	Ethyl ether.....	0.92	3.19	119	137
C <sub>5</sub> H <sub>12</sub> O	Isoamyl alcohol.....	1.24	3.13	157	148

\*  $K_c$  computed for  $n$ -propyl and isobutyl alcohols, and  $K$  observed for isopropyl and  $n$ -butyl alcohols.

Two formulae have been proposed for computing the conductivity of a binary liquid mixture. One (21) is  $(v_1 + v_2)K^n = v_1K_1^n + v_2K_2^n$ , where  $v_1, v_2$  are the volumes of the pure constituents and  $n$  is a constant which depends upon the constituents. The other, proposed by the compilers, is new and is easy to use if a table of hyperbolic sines is available,  $v. (3, 28, 29)$ . It is  $K \sinh 100\mu = K_1 \sinh p_1\mu + K_2 \sinh p_2\mu$ , where  $p_1$  and  $p_2$  are the percentages, by weight, of the constituents and  $\mu$  depends upon the constituents, and the temperature. Satisfactory data for testing the formula are available for only 6 mixtures, for these it fits well within the limits of experimental error; for values of  $\mu$ , see Table 7.

TABLE 7.—THERMAL CONDUCTIVITY OF BINARY LIQUID MIXTURES AT 20°C (12, 20, 21)

$K \sinh (100\mu) = K_1 \sinh p_1\mu + K_2 \sinh p_2\mu$ ;  $G$  = degree of confidence (see p. 226).

Constituents	$100\mu_{20^\circ}$	$G$
Water-ethyl alcohol.....	1.34	B
Water-methyl alcohol.....	1.30	B
Water-glycerol.....	0.40	C
Water-acetic acid.....	0.90	C
Methyl alcohol-ethyl alcohol.....	0.48	B
Glycerol-ethyl alcohol.....	0.98	B

In general the formula  $K = K_w(1 - \alpha p)$  represents the conductivity of aqueous solutions,  $p$  = grams of solute per 100 g. of solution,  $K_w$  = conductivity of pure water at the same temperature, and  $\alpha$  (= depression coefficient) is a constant depending upon the solute and probably upon the temperature. In certain cases (notably HCl) the linear relation is not applicable, and for some dilute solutions one observer finds  $K > K_w$  and increases with the concentration (see Table 8); additional observations are desirable. For aqueous solutions containing two solutes, in general,  $\alpha p = \alpha_1 p_1 + \alpha_2 p_2$ . (See Table 11.)

TABLE 8.—ILLUSTRATING EXCEPTIONAL VARIATION OF THERMAL CONDUCTIVITY WITH CONCENTRATION: AQUEOUS SOLUTIONS (18)

For these solutions  $K > K_w$  and increases with the concentration ( $C$ ). Accuracy very low, degree of confidence = D.

Unit of  $C = 1$  g-equiv./liter; of  $K = 10^{-6}$  watt/(cm °C); tabular values are  $K$ ;  $t = 9^\circ\text{C}$ .

Solute	$C$	0	0.0001	0.001	0.01	0.1	1
C <sub>2</sub> HCl <sub>3</sub> O <sub>2</sub> , trichloroacetic acid.....		510	518	611	678	725	810
H <sub>3</sub> BO <sub>3</sub> , boric acid.....		510	513	519	563	584	
KCl, * potassium chloride...		510	511	565	637	726	740

\* Data at variance with those of other observers, cf. Table 11.

TABLE 9.—THERMAL CONDUCTIVITY OF LIQUIDS UNDER PRESSURE (4)

Quantity tabulated is  $r_t \equiv 1000 K_p/K_a$  where  $K_p$  = conductivity at temperature  $t$  and pressure  $P$ , and  $K_a$  = conductivity at temperature  $t$  and 1 atm.

Unit of  $P = 1000$  kg/cm<sup>2</sup> = 967.8 atmosphere = 14 223 lb./in<sup>2</sup>; grade = C (v. p. 226).

Formula	Substance	$P$	2	4	6	8	10	12	$t$
H <sub>2</sub> O	Water.....		1113	1210	1293	1366	1428	F*	30
CS <sub>2</sub>	Carbon disulfide.....		1310	1512	1663	1783	1880	1962	30
CH <sub>3</sub> O	Methyl alcohol.....		1342	1557	1724	1864	1986	2097	30
C <sub>2</sub> H <sub>5</sub> Br	Ethyl bromide.....		1327	1517	1657	1768	1858	1928	30
C <sub>2</sub> H <sub>5</sub> I	Ethyl iodide.....		1232	1394	1509	1592	1662	1724	30
C <sub>2</sub> H <sub>5</sub> O	Ethyl alcohol.....		1363	1574	1744	1888	2014	2122	30
C <sub>3</sub> H <sub>6</sub> O	Acetone.....		1315	1511	1659	1786	1900	F*	30
C <sub>3</sub> H <sub>7</sub> O	Isopropyl alcohol.....		1352	1570	1743	1894	2028	2150	30
C <sub>4</sub> H <sub>10</sub> O	$n$ -Butyl alcohol.....		1307	1495	1648	1780	1900	2008	30
C <sub>4</sub> H <sub>10</sub> O	Ether.....		1509	1800	2009	2177	2322	2451	30
C <sub>5</sub> H <sub>12</sub>	$n$ -Pentane.....		1483	1777	1987	2163	2325	2481	30
C <sub>5</sub> H <sub>12</sub> O	Isoamyl alcohol.....		1320	1524	1686	1828	1955	2069	30
C <sub>7</sub> H <sub>8</sub>	Toluene.....		1286	1470	1604	1716	F*		30
	Petroleum ether.....		1460	1752	1970	2143	2279	2379	30
H <sub>2</sub> O	Water.....		1123	1225	1308	1379	1445	1506	75
CS <sub>2</sub>	Carbon disulfide.....		1366	1607	1789	1935	2054	2154	75†
CH <sub>3</sub> O	Methyl alcohol.....		1365	1601	1785	1939	2072	2191	75†
C <sub>2</sub> H <sub>5</sub> Br	Ethyl bromide.....		1390	1609	1772	1907	2022	2121	75†
C <sub>2</sub> H <sub>5</sub> I	Ethyl iodide.....		1265	1442	1570	1671	1757	1837	75
C <sub>2</sub> H <sub>5</sub> O	Ethyl alcohol.....		1400	1650	1845	2007	2152	2278	75†
C <sub>3</sub> H <sub>6</sub> O	Acetone.....		1325	1554	1738	1891	2024	2137	75†
C <sub>3</sub> H <sub>7</sub> O	Isopropyl alcohol.....		1399	1638	1812	1962	2093	2211	75
C <sub>4</sub> H <sub>10</sub> O	$n$ -Butyl alcohol.....		1358	1559	1720	1859	1985	2099	75
C <sub>4</sub> H <sub>10</sub> O	Ether.....		1518	1814	2043	2231	2394	2537	75†
C <sub>5</sub> H <sub>12</sub>	$n$ -Pentane.....		1534	1855	2112	2335	2543	2740	75†
C <sub>5</sub> H <sub>12</sub> O	Isoamyl alcohol.....		1348	1557	1724	1868	1998	2126	75
C <sub>7</sub> H <sub>8</sub>	Toluene.....		1355	1573	1738	1872	1987	2089	75
	Petroleum ether.....		1466	1780	2026	2232	2409	2561	75†
	Kerosene.....		1314	1502	1654	1792	1925	2054	75

\* Freezes under this pressure.

† Boils at 75°C and 1 atmosphere, but liquid at pressure of a few 100 kg cm<sup>2</sup>;  $K_a$  obtained by extrapolating the ( $K_p, P$ ) graph.

TABLE 10.—THERMAL CONDUCTIVITY ( $K$ ) OF PURE AND OF MISCELLANEOUS LIQUIDS

For conductivity of solutions, see Table 11; of binary mixtures, see Table 7

Section I contains all liquids for which the data are of grade A or B; see p. 226; Section II contains pure organic liquids, grades C and D; Section III contains miscellaneous liquids. For change in  $K$  on fusion, see C<sub>7</sub>H<sub>9</sub>N, C<sub>10</sub>H<sub>9</sub>N, C<sub>10</sub>H<sub>14</sub>O, CaCl<sub>2</sub>·6H<sub>2</sub>O, Na<sub>2</sub>HPO<sub>4</sub>·12H<sub>2</sub>O.

$K_t = K_{20} [1 + \alpha(t - 20)]$ ,  $0^\circ < t < 80^\circ\text{C}$ ; the true value of  $K_{20}$  is believed to lie between "Min." and "Max."  $G$  = grade of the data;  $t$  = centigrade temperatures; M. P. = melting point, °C. Only for liquids in Section I are values of "Min.," "Max." and  $\alpha$  given.  $s$  = solid;  $l$  = liquid.

Unit of  $K = 10^{-6}$  watt/(cm °C) = 100 erg/(cm sec °C) =  $2.389 \times 10^{-6}$  cal<sub>15</sub>/(cm sec °C); of  $\alpha = (1^\circ\text{C})^{-1}$

I. Liquids: grades A and B (v. p. 226)

Formula	Substance	$K_{20}$	Min.	Max.	$1000\alpha$	$G$	Lit.
H <sub>2</sub> O	Water.....	587	580	595	+2.81	A	(4, 14, 16, 20, 25, 35); cf. (6, 7, 10, 18, 22, 23, 24, 26)
CS <sub>2</sub>	Carbon disulfide.....	161	145	175	-1.18	B	(4, 9, 35); cf. (6, 10, 24)
CH <sub>3</sub> O	Methyl alcohol.....	209	200	220	-0.53	A	(4, 9, 20, 35); cf. (6, 11)



TABLE 10—(Continued)

Formula	Substance	$K_{20}$	Min.	Max.	1000 $\alpha$	$G$	Lit.
$C_2H_5O$	Ethyl alcohol.....	182	172	190	-0.71	A	(4, 12, 16, 20, 35); cf. (6, 7, 10, 11, 23, 34)
$C_2H_5Br$	Ethyl bromide.....	121	100	130	-0.99	B	(4); cf. (35)
$C_2H_5I$	Ethyl iodide.....	111	90	120	-0.33	B	(4); cf. (35)
$C_3H_6O$	Acetone.....	179	160	190	-1.34	B	(4, 9)
$C_3H_7O$	Isopropyl alcohol.....	153	140	170	-0.24	B	(4, 9)
$C_3H_7O_2$	Glycerol.....	290	275	310	+2.62	A	(9, 20, 31, 35, 36); cf. (7, 10, 22, 23, 34)
$C_4H_{10}O$	<i>n</i> -Butyl alcohol.....	168	140	200	-0.50	B	(4)
$C_4H_{10}O$	Ether.....	138	120	145	-0.47	B	(4, 9); cf. (10, 34, 35)
$C_5H_{12}$	<i>n</i> -Pentane.....	136	110	150	-1.03	B	(4); cf. (9)
$C_5H_{12}O$	Isoamyl alcohol.....	148	120	160	-0.38	B	(4); cf. (11, 35)
$C_7H_8$	Toluene.....	160	140	190	-1.44	B	(4, 9, 17, 30, 35)
	Petroleum ether.....	131	120	160	-0.71	B	(4); cf. (10, 36)
	Kerosene.....	151	130	170	-1.46	B	(4); cf. (6, 36)

## II. Pure organic liquids: grades C and D (v. p. 226)

Formula	Substance	$t$	$K_t$	$G$	Lit.
$CCl_4$	Carbon tetrachloride.....	0	110	C	(9); cf. (35)
$C_2Cl_4$	Tetrachloroethylene.....	22	126	C	(30)
$CHCl_3$	Chloroform.....	12	138	D	(34, 35)
$CH_2O_2$	Formic acid.....	12	271	D	(35)
$C_2H_4Br_2$	1, 2-Dibromoethane.....	21	118	C	(30)
$C_2H_4Cl_2$	1, 2-Dichloroethane.....	20	158	C	(30)
$C_2H_4O_2$	Acetic acid.....	20	172	C	(20, 35)
$C_2H_6O_2$	Glycol.....	0	265	C	(9)
$C_3H_6O$	Acetone.....	20	179	B	(4, 9)
$C_3H_6O_2$	Ethyl formate.....	12	169	D	(35)
$C_3H_6O_2$	Methyl acetate.....	12	171	D	(35); cf. (11)
$C_3H_6O_2$	Propionic acid.....	12	173	D	(35)
$C_3H_7Br$	Propyl bromide.....	12	126	D	(35)
$C_3H_7Cl$	Propyl chloride.....	12	136	D	(35)
$C_3H_7I$	Propyl iodide.....	12	111	D	(35)
$C_3H_8O$	Propyl alcohol.....	0	167	C	(9); cf. (35)
$C_4H_7NS$	Allyl isothiocyanate.....	12	170	D	(35)
$C_4H_8O_2$	<i>n</i> -Butyric acid.....	12	163	D	(35)
$C_4H_8O_2$	Isobutyric acid.....	12	157	D	(35)
$C_4H_8O_2$	Ethyl acetate.....	19	174	C	(30); cf. (11, 35)
$C_4H_8O_2$	Propyl formate.....	12	162	D	(35)
$C_4H_9Br$	Isobutyl bromide.....	12	134	D	(35)
$C_4H_9Cl$	Isobutyl chloride.....	12	134	D	(35)
$C_4H_9I$	Isobutyl iodide.....	12	106	D	(35)
$C_4H_{10}S$	Ethyl sulfide.....	12	153	D	(35)
$C_4H_{10}O$	Isobutyl alcohol.....	12	157	D	(35)
$C_5H_{10}O_2$	<i>n</i> -Valeric acid.....	12	152	D	(35)
$C_5H_{10}O_2$	Isovaleric acid.....	12	147	D	(35)
$C_5H_{10}O_2$	Methyl butyrate.....	21	168	C	(30); cf. (35)
$C_5H_{10}O_2$	Propyl acetate.....	12	152	D	(35)
$C_5H_{11}Br$	Amyl bromide.....	12	118	D	(35); cf. (11)
$C_5H_{11}Cl$	Amyl chloride.....	12	136	D	(35)
$C_5H_{11}I$	Amyl iodide.....	12	104	D	(35)
$C_5H_{12}O$	<i>n</i> -Amyl alcohol.....	0	144	C	(9)
$C_5H_{12}O$	Dimethylethyl carbinol..	0	124	C	(9)
$C_6H_5Br$	Bromobenzene.....	12	129	D	(35)
$C_6H_5Cl$	Chlorobenzene.....	12	143	D	(35)
$C_6H_5NO_2$	Nitrobenzene.....	12.5	158	C	(9)
$C_6H_6$	Benzene.....	20	170	D	(9, 11, 34, 35)*
$C_6H_7N$	Aniline.....	0	180	C	(9, 35); cf. (23)
$C_8H_{12}O_2$	Isocaproic acid.....	12	142	D	(35)
$C_8H_{12}O_2$	Ethyl butyrate.....	24	166	C	(30); cf. (35)

Formula	Substance	$t$	$K_t$	$G$	Lit.
$C_6H_{12}O_2$	Methyl valerate.....	21	153	C	(30); cf. (11, 35)
$C_6H_{14}$	Hexane.....	4	142	D	(9, 13)
$C_7H_9N$	<i>p</i> -Toluidine (M. P., 45°C)	26	159 s	C	(20)
		38	138 s	C	(20)
		51	121 l	C	(20)
		64	113 l	C	(20)
$C_7H_{14}O_2$	Amyl acetate.....	12	143	D	(35); cf. (11)
$C_7H_{14}O_2$	Ethyl valerate.....	20	149	C	(30); cf. (11, 35)
$C_7H_{16}$	Heptane.....	4	141	D	(13)
$C_8H_{10}$	<i>o</i> -Xylene.....	21	156	C	(9); cf. (11)†
$C_8H_{10}$	<i>m</i> -Xylene.....	21	155	C	(9, 30); cf. (11)‡
$C_8H_{16}O_2$	Isobutyl butyrate.....	18	144	C	(30)
$C_8H_{18}$	Octane.....	4	157	D	(13)
$C_9H_{10}O_2$	Ethyl benzoate.....	32	160	D	(11)
$C_9H_{18}O_2$	Isobutyl valerate.....	21	137	C	(30)
$C_9H_{18}O_2$	Amyl butyrate.....	18	142	C	(30)
$C_{10}H_9N$	$\alpha$ -Naphthylamine (M. P., 50°C).	25	163 s	C	(20)
		41	146 s	C	(20)
		52	117 l	C	(20)
		62	117 l	C	(20)
$C_{10}H_{14}$	Cymene ( <i>p</i> -methylisopropylbenzene).....	12	132	D	(35); cf. (11)
$C_{10}H_{14}O$	Thymol (M. P., 13°C)...	12	150 s	D	(2)
		13	131 l	D	(2)
$C_{10}H_{20}O_2$	Amyl valerate.....	21	138	C	(30)
$C_{11}H_{14}O_2$	Isobutyl benzoate.....	21	144	C	(30)
$C_{12}H_{16}O_2$	Amyl benzoate.....	23	141	C	(30); cf. (11)

## III. Miscellaneous liquids

Formula	Substance	$t$	$K_t$	$G$	Lit.
$CaCl_2 \cdot 6H_2O$ §	Calcium chloride (M. P., 29°C).	24	627 s	D	(20)
		30	477 l		
		41	443 l		
$Na_2HPO_4 \cdot 12H_2O$	Disodium phosphate (M. P., 35°C).	24	548 s	C	(20)
		32	514 s		
		39	502 l		
		49	477 l		
	Olive oil.....	4	175	C	(31, 33); cf. (7, 34)
	Castor oil.....	4	181	C	(31, 33)
	Poppy oil.....	4	169	C	(31, 33)
	Turpentine oil.....	12	127	D	(35); cf. (6, 10)
	Sweet almond oil....	4	177	D	(32, 33)
	Sesame oil.....	4	175	D	(32, 33)
	Lemon peel oil.....	6	170	D	(7, 34)
	Peanut oil.....	4	168	D	(32, 33)
	Nutmeg oil.....	4	156	D	(32, 33)
	Copaiba oil.....	4	115	D	(32, 33)
	Canada balsam.....	4	115	D	(32, 33)
	Kerosene.....	See section I			
	Petroleum ether.....	See section I			
	Tar ("Holzteer")...	79.5	135	D	(8)
	Vaseline.....	15	184	C	(20); cf. (24)

\* In deriving  $K_t$ , the values for alcohol and toluene were considered.  
† In deriving  $K_t$ , the value for *m*-xylene was considered.  
‡ In deriving  $K_t$ , the value for toluene was considered.  
§ Part of the apparent change on fusion may be due to a difference in the experimental errors pertaining to the measurement of  $K$  in solid and in liquid phase.



TABLE 11.—THERMAL CONDUCTIVITY ( $K$ ) OF AQUEOUS SOLUTIONS

$K = K_w(1 - 10^{-5}\alpha p)$ ,  $K_w$  = conductivity of water at same temperature as applies to  $K$ ,  $p$  grams of solute per 100 g of solution. In section II, computed conductivity is  $K_c = K_w[1 - 10^{-5}(\alpha_1 p_1 + \alpha_2 p_2)]$ , the  $\alpha$ 's being those given in section I. Data are relative to the following values for water:  $K_{17.5} = 583$ ,  $K_{20} = 587$ ,  $K_{22} = 606.8$ , unit is  $10^{-5}$  watt/(cm °C). For exceptional solutions, see text and Table 8;  $G$  = grade of the data (v. p. 226).

Unit of  $K = 10^{-5}$  watt/(cm °C).

## I. One Solute

Solute	$p$	$K_{22}$	$\alpha$	$G$	Lit.
HCl.....	12.5	528		C	(14)
	25	482			
	38	441			
H <sub>2</sub> SO <sub>4</sub> .....	30	521	464	C	(14, 35); cf. (6)
	60	438			
	90	354			
NH <sub>3</sub> .....	26	452*	885	B	(20)
C <sub>12</sub> H <sub>22</sub> O <sub>11</sub> †.....	25	506*	556	B	(20)
	52	422*			
	67	361*			
Pb(NO <sub>3</sub> ) <sub>2</sub> .....	36	563	200	C	(14)
ZnCl <sub>2</sub> .....	17.5	555	473	C	(14)
	35	508	473	C	(14)
ZnSO <sub>4</sub> .....	16	578	275	C	(14, 34)
	32	555			
CuSO <sub>4</sub> .....	18	577	272	C	(14, 34)
MgCl <sub>2</sub> .....	11	576	488	C	(14)
	22	540			
MgSO <sub>4</sub> .....	22	592	144	C	(14)
CaCl <sub>2</sub> .....	15	579	309	C	(14)
	30	550			
SrCl <sub>2</sub> .....	25	574	216	C	(14)
Sr(NO <sub>3</sub> ) <sub>2</sub> .....	36	560	214	C	(14)
BaCl <sub>2</sub> .....	21	584	176	C	(14)
NaCl.....	12.5	587	248	C	(14)
	25	570			
NaBr.....	20	564	302	D	(14)
	40	539			
Na <sub>2</sub> SO <sub>4</sub> .....	10	606	20	C	(14)
NaNO <sub>3</sub> .....	22	571	235	C	(14)
	44	549			
Na <sub>2</sub> CO <sub>3</sub> .....	10	587	320	C	(14)
NaC <sub>2</sub> H <sub>3</sub> O <sub>2</sub> †.....	13	589	210	D	(14)
	23.1	578			
KOH.....	21	579	221	C	(14)
	42	550			
KCl.....	20	558	400	C	(14); cf. (18)
KBr.....	40	492	473	D	(14)
KI.....	20	527	586	D	(14)
	40	472			
	60	395			
K <sub>2</sub> SO <sub>4</sub> .....	10	603	(70)	C	(14)
KNO <sub>3</sub> .....	10	591	347	C	(14)
	20	559			
K <sub>2</sub> CO <sub>3</sub> .....	20	575	265	C	(14)

## II. Two solutes (14); grade C (v. p. 226)

S <sub>1</sub>	S <sub>2</sub>	P <sub>1</sub>	P <sub>2</sub>	$K_{22}$	$K_c$
Pb(NO <sub>3</sub> ) <sub>2</sub>	Sr(NO <sub>3</sub> ) <sub>2</sub>	16	18	564	564
CuSO <sub>4</sub>	ZnSO <sub>4</sub>	8	12	569	573
BaCl <sub>2</sub>	CaCl <sub>2</sub>	7	12	575	577
NaCl	KCl	10	10	575	567
NaNO <sub>3</sub>	KNO <sub>3</sub>	20	10	563	557

III. Sea water (19);  $t = 17.5^\circ\text{C}$ ; grade C (v. p. 226)

$p\%$ .....	0	1	2	3	3.5	4
$K$ .....	583	569	563	560	558	557

\*  $K_{22}$  for NH<sub>3</sub>,  $d = 0.907$  g/cm<sup>3</sup>. † Cane sugar. ‡ Sodium acetate. §  $p$  = grams of total salts per 100 g of sea water.

## LITERATURE

(For a key to the periodicals see end of volume)

- (1) van Aubel, 7, 23: 336; 99. (2) Barus, 3, 23: 431; 92. (3) Blakeley, 67, Special Publ.; 1890. (4) Bridgman, 65, 59: 141; 23. (5) Chree, 3, 24: 1; 87. (6) Chree, 5, 42: 300; 87. 42: 30; 87. (7) Christiansen, 8, 14: 23; 81. (8) Ernst, 75, 111: 923; 02. (9) Goldschmidt, 63, 12: 417; 11. (10) Gräts, 8, 18: 79; 83. 25: 337; 85. (11) de Heen, 186, 18: 192; 89. (12) Henneberg, 8, 26: 146; 89. (13) Hernquist, 20, 8: No. 9; 13. (14) Jager, 75, 99 IIa: 245; 90. 428, 27: 42; 91. (15) Jager, 75, 102 IIa: 253, 483; 93. (16) Jakob, 8, 63: 537; 20. 76, 1920: 406. (17) Jakob, Verlag Ver. deut. Ing., 1922: 137. (18) Kohlrausch, Diss., Rostock, 1904. (19) Krümmel, Meteor. Zeits., 24: 525; 07. Handb. der Ozeanographie, I: 281. Stuttgart, Engelhorn, 1907. (20) Lees, 62, 191: 399; 98. (21) Lees, 3, 42: 286; 00. (22) Lorberg, 8, 14: 291; 81. (23) Mache and Tagger, 75, 116: 1105; 07. (24) Melmer, 75, 120: 269; 11. (25) Milner and Chattock, 3, 48: 46; 99. (26) Nusselt, 380, 28: 477, 490; 15. (27) Sluginov, 53, 23: 456; 91. 51, 1: 405; 92. (28) Smithsonian Mathematical Tables. Washington, D. C., Government Printing Office. (29) Smithsonian Physical Tables. Washington, D. C., Government Printing Office. (30) Stankevič, 427, 1890: 383. (31) Streit, Diss., Zürich, 1910. (32) Wachsmuth, Diss., Leipzig, 1892. 8, 48: 158; 92. (33) Wachsmuth, 63, 3: 79; 01. (34) Weber, 8, 10: 103, 304, 472; 80. (35) Weber, 78, 1885: 809. 428, 22: 116; 86. (36) Weber, 8, 11: 1047; 03.

## GLASSES

See also Vol. II, p. 101 and errata sheet

Many of the best measurements of the conductivity of glasses have been merely incidental to the measurement of some other quantity; in such cases the exact composition of the glass has not been known and the kind of glass has been indicated only vaguely. The two observers (3, 13) who have especially studied the variation of  $K$  with the composition, have not used the most convincing methods for measuring  $K$ . Consequently, for values of  $K$  for glasses of known composition, we must rely on the work of a single observer, but his values receive considerable support from the observations of others who have less precisely defined the character of their glasses.

TABLE 12.—THERMAL CONDUCTIVITY ( $K$ ) OF GLASSES OF TYPICAL COMPOSITIONS

Value of temperature coefficient is uncertain; it is probably  $> 0$  (2, 6, 8, 9, 14).

OC = ordinary crown; BC = borosilicate crown; PPC = potash phosphate crown; BPC = baryta phosphate crown; HLS = heavy lead sand; OF = ordinary flint; HF = heavy flint.

Unit of  $K = 10^{-5}$  watt/(cm °C); composition is by weight; grade C (v. p. 226).

Glass =	OC	BC	PPC	BPC	HLS	OF	HF
$K_{25}$ .....	1000*	1130	825	760	670	855	720
Lit.....	*	(3); cf. (2, 13)	(3); cf. (2, 13)	(3); cf. (2, 13)	(3); cf. (13)	(3, 7); cf. (2, 10, 13)	(3); cf. (2, 13)
P <sub>2</sub> O <sub>5</sub> .....			69.5	59.5			
As <sub>2</sub> O <sub>5</sub> .....			1.5	1.5			0.2
SiO <sub>2</sub> .....	65.9	71.0			20.0	45.1	29.3
PbO.....					80.0	46.4	67.5
ZnO.....	2.0						
B <sub>2</sub> O <sub>3</sub> .....	2.5	14.0	3.0	3.0			
Al <sub>2</sub> O <sub>3</sub> .....		5.0	10.0	8.0			
MgO.....			4.0				
BaO.....	9.6			28.0			
Na <sub>2</sub> O.....	5.0	10.0				0.5	
K <sub>2</sub> O.....	15.0		12.0			8.0	3.0

\* Grade B; limits of  $K_{25} = 980$  to  $1090$ ; (3, 7); cf. (1, 9, 10, 12, 13, 14, 15, 16).



TABLE 13.—CONTRIBUTIVE THERMAL CONDUCTIVITIES (*O*) OF OXIDES IN GLASSES (3); cf. (13)

$100 K = O_1 p_1 + O_2 p_2 + \dots + O_n p_n$ ,  $K$  = thermal conductivity of the glass,  $p_n$  = percentage by weight of oxide "n." [For other formulae, see (3, 13, 19).]

Example: Typical flint glass, 46.4% PbO, 45.1% SiO<sub>2</sub>, 0.5% Na<sub>2</sub>O, 8.0% K<sub>2</sub>O; hence,  $100 K = 518 \times 46.4 + 1320 \times 45.1 + 294 \times 0.5 + 250 \times 8.0 = 85714$ ;  $K = 857$  of the units of the table =  $857 \times 10^{-5}$  watt/(cm °C) = 0.00857 watt/(cm °C), which agrees well with critical value of Table 12.

Unit of  $O_p/100 = 10^{-5}$  watt/(cm °C) =  $2.389 \times 10^{-6}$  cal<sub>15</sub>/(cm sec °C);  $t = 45^\circ\text{C}$ .

Oxide	<i>O</i>	Oxide	<i>O</i>
P <sub>2</sub> O <sub>5</sub> .....	979	Al <sub>2</sub> O <sub>3</sub> .....	1082
As <sub>2</sub> O <sub>5</sub> .....	-5506	MgO.....	1552
Sb <sub>2</sub> O <sub>3</sub> .....	118	CaO.....	396
SiO <sub>2</sub> .....	1320	BaO.....	526
PbO.....	518	Na <sub>2</sub> O.....	294
ZnO.....	504	K <sub>2</sub> O.....	250
B <sub>2</sub> O <sub>3</sub> .....	837		

## LITERATURE

(For a key to the periodicals see end of volume)

- (1) Dina, 59, 9: 461; 99. (2) Eucken, 8, 34: 185; 11. (3) Focke, 8, 67: 132; 99. (4) Georgiewski, 53, 35: 609; 03. (5) Hecht, 8, 14: 1008; 04. (6) Krüger, 8, 5: 919; 01. (7) Lees, 62, 183: 481; 92. (8) Lees, 5, 62: 286; 98. (9) Lees, 62, 191: 399; 98. (10) Meyer, 188, 1888: 41. 8, 34: 596; 88. (11) Niven and Geddes, 5, 87: 535; 12. (12) Oddone, 22, 6 I: 286; 97. (13) Paalhorn, Diss., Jena, 1894. (14) Peirce and Willson, 65, 34: 3; 98. (15) Tadokoro, 159, 10: 339; 21. (16) Venke, 188, 1891: 121. (17) Vesely, 100, 44: 441; 11. (18) Voigt, 188, 1898: 166. 8, 64: 95; 98. (19) Winkelmann, 8, 67: 160; 99. (20) Winkelmann, 8, 67: 794; 99. (21) Winkelmann and Schott, 8, 51: 730; 94.

## CRYSTALS

The isothermal surfaces surrounding a single, constant, point source of heat in the interior of a crystal of any type are coaxial ellipsoids of constant axial ratios, provided that the distance of the surface of the crystal from the source is great as compared with that of the isothermal surface. The thermal conductivities (*A*, *B*, *C*) along the several principal axes of these ellipsoids are proportional to the squares of the lengths of the semi-axes. These are the *principal* conductivities of the crystal, and the surface  $\frac{x^2}{A} + \frac{y^2}{B} + \frac{z^2}{C} = 1$  is called the *thermal ellipsoid* of the material.

In the mathematically most general case there are certain rotation coefficients (67), but these have never been found in any actual crystal; gypsum, dolomite, apatite, and erythrite have been carefully examined for them (63, 64, 75); for these crystals they are certainly <0.05% of *A*. Hence the conductivity of a crystal is completely specified when the values of *A*, *B*, and *C* and the orientation of the thermal ellipsoid with reference to the crystal-line axes are known, the conductivity along any<sup>1</sup> axis of the thermal ellipsoid being equal to the square of the length of that semi-axis.<sup>2</sup>

If  $A = B = C$ , the crystal is thermally isotropic; if  $A = B \neq C$ , it is uniaxial, the axis being in the direction of the *C* axis, if  $A \neq B \neq C \neq A$ , the thermal ellipsoid has two, and only two, central circular sections, and the crystal is thermally biaxial, the directions of the axes being the normals to these sections. If, of *A*, *B*, *C*, the one of intermediate value is less than the average of the other two, the crystal is said to be thermally +, in the contrary case it is —; in the former case the thermal ellipsoid is prolate, in the latter it is oblate.

By convention, the crystallographic axes of a crystal are denoted by the letters *a*, *b*, *c*, if three; if more than three, the interchangeable ones are denoted by *a*<sub>1</sub>, *a*<sub>2</sub>, . . . . If there is a unique axis,

<sup>1</sup> Not merely along a principal axis.

<sup>2</sup> For an experimental test by directly measuring conductivities other than principal ones, see (12).

that is taken as the *c* axis, except in the monoclinic system, where it is the *b* axis. When the crystal is in its normal position, *c* is vertical and the plane including *c* and the line of sight either includes the *a* axis or bisects the angle between two interchangeable *a* axes which are not mutually perpendicular. If  $a \neq b \neq c \neq a$  and axes are mutually perpendicular (orthorhombic system) the axes are always so chosen that  $a < b$ , and usually so that  $a < b < c$ ; *a* is called the brachy-axis, *b* the macro-axis. In the monoclinic system, *b* is the unique axis, *c* is the inclined axis which is parallel to the prismatic faces; the normal orientation of the crystal is such that *a* slopes downwards towards the observer. When there is uncertainty regarding which faces belong to the prism, a standard work on mineralogy should be consulted. The acute angle between *c* and *a* is denoted by  $\beta$ .

In the triclinic system *c* is the axis parallel to the prismatic faces (same uncertainty as before), usually  $a < b$ , and the orientation is such that the *a* axis slopes downward towards the observer. The angles between the positive directions of the axes are denoted by  $\alpha$ ,  $\beta$ ,  $\gamma$ ;  $\alpha = \angle bc$ ,  $\beta = \angle ca$ ,  $\gamma = \angle ab$ .

TABLE 14.—TYPE AND ORIENTATION OF THERMAL ELLIPSOID

Crystal system	Optical and thermal character	Thermal axes and orientation
Cubic.....	Isotropic	$A = B = C$
Trigonal.....	Uniaxial	$A = B \neq C$ ; <i>C</i> coincides with <i>c</i> . If $A = B < C$ , crystal is +; if $A = B > C$ , it is —.
Tetragonal.....		
Hexagonal.....		
Orthorhombic.....	Biaxial	$A \neq B \neq C \neq A$ ; <i>A</i> , <i>B</i> , <i>C</i> coincide with <i>a</i> , <i>b</i> , <i>c</i> .
Monoclinic.....	Biaxial	$A \neq B \neq C \neq A$ ; <i>B</i> coincides with <i>b</i> , <i>C</i> is that one of the other axes which is nearest to <i>c</i> ; $\theta = \angle cC$ measured in direction of $\angle ca$ .
Triclinic.....	Biaxial	$A \neq B \neq C \neq A$ . For no crystal of this system have the thermal properties been completely investigated; for important work on CuSO <sub>4</sub> ·5H <sub>2</sub> O, see (54).

## Empirical Relations

**Thermal.**—There is some indication (see Table 16) that  $K \propto T^{-1}$  if  $T > 25^\circ\text{K}$ ; in region  $20^\circ\text{K}$  to  $25^\circ\text{K}$ , *K* increases rapidly as *T* is reduced; diamond, however, shows little change until *T* is small, and then seems to decrease markedly. Until additional observations have been made we can do no more than assume that  $K \propto T^{-1}$  holds approximately over ordinary ranges of *T* (24, 25, 28). On basis of same observations, it has been suggested that the smaller the number of atoms in the molecule of the crystal and the higher the melting point the greater is *K*. At their melting points, crystals of di- or tri-atomic molecules have approximately the same *K* (24).

**Light.**—In specimens of Se which are electrically sensitive to illumination, the thermal conductivity is increased by illumination, but much less than the electrical. The effect is difficult to detect. It is claimed that the effect increases with the wavelength of the light and decreases with the temperature (4, 45, 53, 62).

**Electrical.**—It is claimed that the higher the electrical, the lower the thermal conductivity, and that whatever increases the former reduces the latter. (For theoretical treatment, see (32).) On the other hand, for any single crystal it is maintained that as the orientation changes, the reciprocal of *K* varies linearly with the electrical volume resistivity (12).



**Magnetic.**—No uniform agreement between direction of maximum  $K$  and that of maximum  $\mu$ ; in calcite they coincide, in gypsum they do not (71); cf. (40, 41). For effect upon Bi, see note, Table 15 (section I).

**Mechanical.**—No data for effect of a pure strain; for effect of longitudinal compression of  $\text{SiO}_2$ , see note, Table 15 (section III); for negligible effect of torsion on Al, see note, Table 15 (section I).

### Theoretical Relations

As the quantum theory has developed, several relations connecting  $K$  with certain atomic constants have been proposed (16, 17, 18, 23). Unfortunately, they can not be satisfactorily tested until more data are available. The type of formula is illustrated by the following expression for  $K$ , which is based upon considerations of the oscillation of the atoms in the space lattice (23):

$$K = 3\pi n k_0 \nu N a \left( \frac{h\nu}{k_0 T} \right)^2 e^{h\nu/k_0 T} / 2(e^{h\nu/k_0 T} - 1)^{3/2}$$

where  $n$  = a numerical factor depending on the character of the space lattice;  $k_0$  = Boltzmann's gas constant ( $1.37 \times 10^{-16}$  erg deg.<sup>-1</sup>);  $\nu$  = frequency of one of the lines in the "rest-strahlen" of Rubens;  $N$  = number of atoms per unit area perpendicular to the direction of flow of heat in the crystal;  $a$  = "centered distance" between two neighboring atoms in the direction of flow of heat;  $h$  = Planck's constant ( $6.554 \times 10^{-27}$  erg sec);  $T$  = absolute temperature.

TABLE 15.—THERMAL CONDUCTIVITY OF CRYSTALS

For position of axes, see Table 14

$A, B, C$  = principal conductivities,  $G$  = grade of accuracy (see p. 226);  $S$  = chemical symbol;  $t$  = temperature, °C; Hex, Mon, Rho, Tri, Tet denote the crystal systems hexagonal, monoclinic, orthorhombic, trigonal, tetragonal. The crystals are arranged in the table in accordance with the usual scheme except that all crystals containing Si have been grouped together under the Si position, and of these, all containing Al have been grouped under the SiAl position.

TABLE 15.—(Continued)

Unit of  $A, B, C$  = 1 watt/cm °C =  $10^7$  cgs =  $10^7$  erg/(cm sec °C) = 0.239 cal/(cm sec °C).

### I. Elementary substances

$S$	System	$t$	$A$	$A/C$	$G$	Lit.
Al*	Cub	30	2.08		$C$	(14)
Bi	Tri	18	0.0924	1.39†	$A$	(33, 36, 44, 55); cf. (34, 35, 46)
C‡	Cub	0	2 ca.		$D$	(25)
C§	Tri	30	3.55	4.0	$C, D$	(35, 37, 38)
Cu	Cub	0	4.1		$C$	(60)
Sb	Tri			2.53	$C$	(34, 35)
Si	Cub	30	0.84		$C$	(37, 38)
Te	Hex			0.66	$C$	(35)

\* A twist of 1.04° per cm produces no change > 0.1 %.

† Magnetic field ( $H$ ) = 4980 gauss, normal to  $c$ , increases  $A/C$  by 26.8 % (44).

‡ Diamond. § Graphite.

### II. Compounds: cubic crystals, $t = 0^\circ\text{C}$ ; $G = D$ ;

$A = B = C = K$

Formula	$K$	Lit.
TlCl.....	0.00978	(28)
TlBr.....	0.00815	(28)
AgCl.....	0.0109	(28)
	0.0110*	(28)
AgBr.....	0.0103	(28)
CaF <sub>2</sub> .....	0.103†	(24); cf. (56)
NaCl.....	0.0697‡	(24); cf. (70, 76)
NaClO <sub>3</sub> .....	0.0111	(24)
KCl.....	0.0696§	(24, 25, 28)
KI.....	0.0502	(28)
KCr(SO <sub>4</sub> ) <sub>2</sub> ·12H <sub>2</sub> O.....	0.00554	(24)

\* Cerargyrite, hornsilver. † Fluorite. ‡ Halite, rock salt. § Sylvite.

### III. Compounds: non-cubic crystals

Formula	Substance	System	Optically	$A/C$	$B/C$	$\theta$	$G$	Lit.
H <sub>2</sub> O*	Ice.....	Tri		< 1				(3, 26); cf. (68)
(NH <sub>4</sub> ) <sub>2</sub> H <sub>2</sub> PO <sub>4</sub>		Tet	—	1.28			$C$	(40)
(NH <sub>4</sub> ) <sub>2</sub> H <sub>2</sub> AsO <sub>4</sub>		Tet	—	1.42			$C$	(40)
Sb <sub>2</sub> S <sub>3</sub>	Stibnite.....	Rho		0.47	0.29		$C$	(34); cf. (33, 61)
Sb <sub>2</sub> (Pb, Cu <sub>2</sub> ) <sub>2</sub> S <sub>6</sub>	Bournonite.....	Rho		0.60	0.58		$C$	(34); cf. (61)
Bi <sub>2</sub> (Te, S) <sub>2</sub> †	Tetradymite.....	Tri		much > 1			$D$	(35)
CO(NH <sub>2</sub> ) <sub>2</sub>	Urea.....	Tet	+	0.79			$D$	(40)
C <sub>4</sub> H <sub>10</sub> O <sub>4</sub>	Erythritol.....	Tet		1.14			$C$	(41)
C <sub>12</sub> H <sub>22</sub> O <sub>11</sub>	Cane sugar.....	†		†			$D$	(24)
SiO <sub>2</sub> ; v. also p. 106	Quartz§.....	Tri	+	0.575‡			$B$	(7, 24, 29, 33, 34, 35, 42, 47, 59, 61, 70); cf. (26, 56)
ZrSiO <sub>4</sub>	Zircon.....	Tet	—	0.81			$C$	(34, 35)
(Zn, Mn) <sub>2</sub> SiO <sub>4</sub> †	Troostite.....	Tri	+	0.73			$C$	(34, 35)
NiSiF <sub>6</sub> ·6H <sub>2</sub> O		Hex	+	0.86			$C$	(40)
(Al silicates)	Mica (biaxial)  .....	Mon		5.84	6.30	v. s.	$C$	(34)
	Mica (ca. uniax)  .....	Mon		5.29	6.00	v. s.	$C$	(34)
Al <sub>2</sub> Si <sub>2</sub> F <sub>10</sub> O <sub>24</sub> †	Topaz.....	Rho		0.94	0.95		$D$	(7)
Al <sub>2</sub> B <sub>2</sub> Si <sub>4</sub> H <sub>11</sub> O <sub>21</sub> ¶	Tourmaline.....	Tri	—	1.35			$D$	(34, 35); cf. (56, 61, 66, 69)
Be <sub>2</sub> Al <sub>2</sub> Si <sub>2</sub> O <sub>18</sub>	Emerald.....	Hex	—	0.81			$C$	(7, 34, 35, 61)
(Mg, Fe) <sub>2</sub> (Al, Fe) <sub>2</sub> Si <sub>11</sub> H <sub>4</sub> O <sub>46</sub> ¶	Staurolite.....	Rho		0.94	0.81		$C$	(34)
(Mg, Fe) <sub>2</sub> Al <sub>2</sub> Si <sub>2</sub> H <sub>8</sub> O <sub>18</sub> †	Penninite.....	Tri**		1.35			$C$	(34, 35)
Ca <sub>4</sub> Al <sub>2</sub> Si <sub>2</sub> O <sub>28</sub> ††	Scapolite.....	Tet	—	0.71			$C$	(34, 35)
Ca <sub>4</sub> (Al, Fe) <sub>2</sub> Si <sub>2</sub> O <sub>28</sub> ·H <sub>2</sub> O	Epidote.....	Mon		0.87	1.18	+14.5	$C$	(34)
Ca <sub>7</sub> R <sub>4</sub> Al <sub>2</sub> Si <sub>2</sub> O <sub>24</sub> †	Vesuvianite.....	Tet	—	0.90			$D$	(7, 34, 35, 61)
(Na <sub>2</sub> , Ca)Al <sub>2</sub> Si <sub>2</sub> O <sub>12</sub> ·6H <sub>2</sub> O	Chabazite.....	Tri	+	0.97			$D$	(34); cf. (35)



## III. Compounds: non-cubic crystals.—(Continued)

Formula	Substance	System	Optically	A/C	B/C	$\theta$	G	Lit.
$\text{Na}_2\text{K}_2\text{Al}_2\text{Si}_2\text{O}_{10}\dagger$	Nephelite.....	Hex		1.00			C	(35)
$\text{KAlSi}_3\text{O}_8$	Orthoclase.....	Mon		0.63	0.90	4††	C	(34); cf. (56, 61)
$\text{Be}_2\text{SiO}_4$	Phenacite.....	Tri		0.92			C	(35)
$\text{CaFe}_2\text{Si}_2\text{O}_{10}\cdot\text{H}_2\text{O}\ddagger$	Ilvaite.....	Rho		1.33	1.01		C	(34)
$\text{CaMg}_3\text{Si}_2\text{O}_{12}$	Tremolite.....	Mon		0.36	0.57	5	C	(34)
$\text{Ca}(\text{Mg}, \text{Fe})_2\text{Si}_2\text{O}_{12}\dagger$	Hornblende.....	Mon		0.50	0.64	5	C	(34)
$\text{Na}_{13}(\text{Fe}, \text{Ca})_6(\text{Si}, \text{Zr})_2\text{ClO}_{18}\ddagger$	Eudialyte.....	Tri	+	1.28			C	(34, 35)
$\text{K}_2\text{Ca}_3\text{Si}_{16}\text{O}_{41}\cdot 16\text{H}_2\text{O}$	Apophyllite.....	Tet	+	much > 1			D	(35); cf. (34)
$\text{TiO}_2$	Rutile.....	Tet	+	0.62			C	(7, 34, 35, 61)
$\text{TiO}_2$	Octahedrite.....	Tet	—	1.80			C	(35); cf. (34)
$\text{SrSO}_4$	Celestite.....	Rho		1.08	1.17		C	(34)
$\text{SnO}_2$	Cassiterite.....	Tet		0.7			D	(7, 34, 35); cf. (61)
$\text{Pb}_2\text{Cl}_2\text{O}$	Matlockite.....	Tet		much > 1			D	(35)
$\text{Pb}_2\text{Cl}_2\text{CO}_3$	Phosgenite.....	Tet		1.00			C	(35)
$\text{PbSO}_4$	Anglesite.....	Rho		1.25	1.30		D	(34)
$\text{PbS}_2\text{O}_6\cdot 4\text{H}_2\text{O}$		Hex	+	1.03			C	(40)
$\text{Pb}_{10}\text{P}_6\text{Cl}_{12}\text{O}_{24}$	Pyromorphite.....	Hex	—	0.95			C	(34, 35)
$\text{PbMoO}_4$	Wulfenite.....	Tet		1.00			C	(35)
$\text{ZnCO}_3$	Smithsonite.....	Tri		> 1			D	(35)
$\text{ZnO}$	Zincite.....	Tri		> 1			D	(35)
$\text{Hd}(\text{NH}_4)_4\text{Cl}_6$		Hex	+	< 1			D	(40)
$\text{Hg}_2\text{Cl}_2$	Calomel.....	Tet		0.59			C	(35, 61)
$\text{HgS}$	Cinnabarite.....	Tri		0.72			C	(35)
$\text{Cu}(\text{NH}_4)_2\text{Cl}_4\cdot 2\text{H}_2\text{O}$		Tet	—	0.86			C	(40)
$\text{Ag}_3\text{GeS}_6$	Argyrodite.....	Tri		1.23			C	(35)
$\text{MnCO}_3$	Rhodochrosite.....	Tri		> 1			D	(35)
$\text{Fe}_2\text{O}_3$	Hematite (red).....	Tri		1.20†			B	(7, 33, 34, 35); cf. (2, 61)
$\text{FeTiO}_3$	Ilmenite.....	Tri		1.23			D	(35)
$\text{Fe}_7\text{S}_8$	Pyrrhotite.....	Hex		1.14			D	(35)
$\text{FeCO}_3$	Siderite.....	Tri	—	1.12			C	(35); cf. (34)
$\text{NiSO}_4\cdot 6\text{H}_2\text{O}$		Tet	—	1.14			C	(40)
$\text{Al}_2\text{O}_3$	Corundum.....	Tri	+	0.85			C	(35); cf. (34, 61)
$\text{MgCO}_3$	Giobertite.....	Tri	—	1.10			C	(35); cf. (34)
$\text{MgPt}(\text{CN})_4\cdot 7\text{H}_2\text{O}$		Tet	+	1.18			C	(40)
$\text{Mg}_2\text{Fe}(\text{CO}_3)_2$	Mesitite.....	Tri	—	1.12			C	(34, 35)
$\text{CaSO}_4$	Anhydrite.....	Rho		0.94	0.89		C	(34)
$\text{CaSO}_4\cdot 2\text{H}_2\text{O}$	Gypsum.....	Mon		0.64	0.42	+17	C	(34); cf. (11, 59, 61)
$\text{CaS}_2\text{O}_6\cdot 4\text{H}_2\text{O}$		Hex	—	0.92			C	(40)
$\text{Ca}_{10}\text{P}_6(\text{F}, \text{Cl})_2\text{O}_{24}$	Apatite.....	Hex	—	0.85			D	(7, 33, 34); cf. (75)
$\text{CaCO}_3$	Calcite.....	Tri	—	0.84†			A	(7, 34, 35, 42, 61, 70); cf. (56)
$\text{CaCO}_3$	Aragonite.....	Rho		> 1	< 1		D	(34); cf. (7)
$\text{CaCu}(\text{C}_2\text{H}_3\text{O}_2)_4\cdot 8\text{H}_2\text{O}$	Ca Cu acetate.....	Tet	+	0.83			C	(40)
$\text{CaWO}_4$	Scheelite.....	Tet		0.90			C	(35)
$\text{CaCe}_2\text{F}_2\text{C}_2\text{O}_6\ddagger$	Parisite.....	Hex		1.25			C	(35)
$\text{CaMg}(\text{CO}_3)_2$	Dolomite.....	Tri	—	1.10			C	(7, 34, 35); cf. (75)
$\text{BaSO}_4$	Barite.....	Rho		1.13	1.05		C	(34); cf. (7, 56)
$\text{KH}_2\text{PO}_4$		Tet	—	1.45			C	(40)
$\text{KH}_2\text{AsO}_4$		Tet	—	1.29			C	(40)
$\text{K}_2\text{CdCl}_6$		Hex	+	0.87			C	(40)
$2\text{KNa}(\text{NO}_3)_2 + \text{K}_4\text{Fe}(\text{CN})_6$		Hex	—	1.16			C	(40)

\* Thermal conductivity of single crystals of ice has not been studied; indirect evidence (especially from orientation of crystals) indicates  $A < C$ , but can give no estimate of magnitude of  $A/C$  (3, 26); cf. (68).

† Composition variable. In vesuvianite,  $R_1 = \text{Ca}_2$ ,  $(\text{AlOH})_2$ ,  $(\text{AlOH})_4$ , or  $\text{H}_4$ . Hornblende contains Al and Na.

‡ For  $\text{SiO}_2$ ,  $A_{10} = 0.065$  (24, 25, 29, 42, 70); cf. (26, 56, 76), grade B;  $\text{Fe}_2\text{O}_3$ ,  $A_{10} = 0.146$  (35), grade C; Calcite,  $C_{10} = 0.0418$  (42, 70); cf. (24, 56), grade B;  $\text{C}_{12}\text{H}_{12}\text{O}_{11}$ , not cubic, conductivity in direction not stated = 0.0058 at 0°C (24), grade D.

§ Ratio  $A/C$  is increased by pressure || to  $c$ -axis and diminished by pressure  $\perp$  to  $c$ -axis; change in  $A/C$  (pressure not stated) amounted to about 10 % (61); cf. (24).

|| These micas not clearly defined. Conductivity (undefined mica) in direction  $\perp$  plane of cleavage = 0.0057,  $t = 50^\circ\text{C}$  (29); cf. (62).

¶ Composition variable and doubtful. Parisite contains La and Dy.

\*\* Perhaps strictly monoclinic. †† Contains Fe, Na, Cl. ‡‡  $\theta$  varies from  $+4^\circ$  to  $-4^\circ$ .



TABLE 16.—THERMAL CONDUCTIVITY ( $K$ ) OF CRYSTALS: VARIATION WITH TEMPERATURE

It has been suggested that  $K$  varies as  $T^{-1}$ ; compare the values of  $K_T/K_{273}$  with those of  $273/T$ , which are given in last line of the table.  $T$  = absolute temperature, °K. Grade =  $D$  (v. p. 226).

Formula	Substance	$T =$	373	196	195	88	83	Lit.
		Axis	$K_T/K_{273}$					
C	Diamond (1).....	Cubic		1.06		0.85		(25)
	(2).....			1.08		1.02		(25)
	(3).....					0.89		(25)
C <sub>12</sub> H <sub>22</sub> O <sub>11</sub> SiO <sub>2</sub>	Cane sugar.....	*			1.35			(24)
	Quartz (1); <i>v. also</i> p. 106.....	<i>C</i>	0.66		1.44		3.60	(24)
		<i>A, B</i>	0.77		1.39		3.39	(24)
	(2).....	<i>A, B</i>		1.35		2.89		(25)
	(3).....	<i>A, B</i>		1.26		2.74		(25)
CaF <sub>2</sub>	Fluorite.....	Cubic	0.77		1.46		3.77	(24)
CaCO <sub>3</sub>	Calcite.....	<i>A, B</i>	0.83		1.34		3.68	(24)
NaCl	Halite.....	Cubic	0.69		1.50		3.82	(24)
NaClO <sub>3</sub>	Na chlorate.....	Cubic			1.41			(24)
KCl	Sylvite (1).....	Cubic	0.71		1.49		3.00	(24)
	(2).....			1.43		2.61		(24)
		$273/T =$	0.732	1.393	1.400	3.106	3.289	

\* Direction is not stated; crystal is not cubic.

Substance* (25)		$T =$	23.1	23	22.3	22	21.9	21.6	21.4	21
C	Diamond (2).....	Cubic								0.769
	(3).....									0.483
SiO <sub>2</sub>	Quartz (2).....	$A, B$				33.0		35.2		39.4
	(3).....	$A, B$		29.5	32.5		34.4		36.8	
KCl	Sylvite (2).....	Cubic	7.02			7.46				8.40
		$273/T =$	11.82	11.87	12.24	12.41	12.47	12.64	12.76	13.00

\* Continuation of preceding portion of table, same specimens.

## LITERATURE

(For a key to the periodicals see end of volume)

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# FREE AND FORCED CONVECTION OF HEAT FROM BODIES OF SIMPLE SHAPE IN GASES AND LIQUIDS

CHESTER W. RICE

The data are here correlated on the film theory which assumes that the hot body is surrounded by a stationary film of fluid through which the heat is carried entirely by conduction. By this approximation the convection loss from bodies of simple geometric form, under widely different fluid conditions, can be computed by means of a few convenient equations. Such a correlation seems more needed at the present time than a plurality of complex equations giving a more exact representation of specific experimental conditions. When the effects of such specific conditions need to be considered, the original sources should be consulted.

For the method of correlation and summaries of the data used, see (100, 101, 102). The constants there given for the forced convection from cylinders, rough pipes, and large plane surfaces have here been revised to include the more recent data (29, 34, 61). The results obtained for a particular object under given flow conditions can be strictly applied only to a geometrically similar object under geometrically similar flow conditions. The importance of this limitation is well illustrated by the wide divergence found between the results of different investigators, which is mainly due to a lack of complete geometric similarity between the systems tested, rather than to errors of measurement.

The loss by *free convection* is the amount of heat, other than that lost by radiation, which leaves a hot body at rest in a large expanse of unstirred fluid. The loss by *forced convection* is the heat carried away by a stream of fluid flowing over the hot body. Only those cases of forced convection will be considered in which the velocity of the stream is large as compared with that of the natural free convection currents, so that the free convection loss may be neglected.

Heat transfers which are accompanied by a change of state (as between condensing vapors and evaporating liquids) are not considered.

## Symbols

After certain definitions are symbols in [ ]; these indicate in each case the relation of the unit of the quantity defined to the fundamental units, as explained in the next section.

$A$	Area of the surface from which the convective loss is $W_c$ ; [ $l^2$ ].
$a, b$	Experimental exponents depending upon the geometrical shape of the hot body and the type of convection.
$B$	Effective thickness of the film of stationary fluid which surrounds the hot body; [ $l$ ].
$C$	A coefficient, <i>not</i> dimensionless, used in approximate equations for convection from large bodies in air.
$c_p$	Specific heat of the fluid at constant pressure; [ $hm^{-1} \times \theta^{-1}$ ].
$D$	A dimension of reference which serves to define the size of the hot body; [ $l$ ].
$F_1$	The dimensionless quantity $k/(\mu c_p)$ .
$F_2$	The dimensionless quantity $\mu/(\rho \sqrt{agD^3 \Delta(T)})$ .
$F_3$	The dimensionless quantity $\mu/(\rho Dv)$ .
$g$	Acceleration of gravity; [ $lt^{-2}$ ].
$h$	The unit of quantity of heat.
$K, K_s$	Experimentally determined, dimensionless coefficients fixed by the geometrical properties of the system of bodies involved and by the type of convection. $K$ applies to both liquids and gases, $K_s$ to gases only.
$k$	Thermal conductivity of the fluid; [ $hl^{-1}t^{-1}\theta^{-1}$ ].
$l$	The unit of length.

$m$	The unit of mass.
$P$	Pressure of the gas.
$R$	Mechanical resistance to the flow of the fluid through the pipe; = retarding force per unit of area of the pipe; [ $ml^{-1}t^{-2}$ ].
$T, T_1, T_2$	Absolute temperature of the fluid, ambient fluid, and hot body, respectively; [ $\theta$ ].
$T_a$	Average film temperature, $T_a = (T_1 + T_2)/2$ ; [ $\theta$ ].
$T_m$	Geometric mean film temperature, $T_m = \sqrt{T_1 T_2}$ ; [ $\theta$ ].
$\Delta T$	Excess in temperature of the hot surface above that of ambient fluid, $\Delta T = T_2 - T_1$ ; [ $\theta$ ].
$t$	Unit of time.
$v$	Mean velocity of fluid relative to the hot body; [ $lt^{-1}$ ].
$W_c$	Total convective loss from area $A$ per unit of time; [ $ht^{-1}$ ].
$\alpha$	Fractional change in density of the fluid per unit change in temperature; [ $\theta^{-1}$ ]. (For a perfect gas, $\alpha = 1/273$ per $^\circ C$ .)
$\beta, \gamma, \delta, \epsilon$	Exponents used in approximate equation for convection from large bodies in air.
$\theta$	The unit of temperature difference.
$\mu$	Viscosity of the fluid; [ $ml^{-1}t^{-1}$ ].
$\rho$	Density of the fluid; [ $ml^{-3}$ ].
$\Delta\varphi = \int_{T_1}^{T_2} k dT = k_s \Delta T$ , where $k_s$ may be called the effective average conductivity of the fluid between the temperatures $T_1$ and $T_2$ .	

## Units

For any of the equations in this report the units of temperature [ $\theta$ ], of heat [ $h$ ], of length [ $l$ ], of mass [ $m$ ] and of time [ $t$ ] may be chosen as convenient, unless the contrary is definitely stated or definite units are named, but a choice once made should be consistently adhered to for all the quantities involved in the equation under consideration. The unit of each of the other quantities is built up of those named, as indicated in the list of symbols, each symbol in [ ] being replaced by the name of its chosen unit, as in the following examples. Under these conditions the numerical values of dimensionless quantities, such as  $F_1, F_2, F_3, K$ , and  $K_s$ , are independent of the particular choice of units for  $\theta, h, l, m$  and  $t$ . For example, if the units chosen are  $\theta = 1^\circ C, h = 1$  joule,  $l = 1$  cm,  $m = 1$  g, and  $t = 1$  sec, then the unit of  $k[hl^{-1}t^{-1}\theta^{-1}]$ , is 1 joule  $cm^{-1} sec^{-1} (^\circ C)^{-1} = 1$  watt  $cm^{-1} (^\circ C)^{-1}$ , that of  $c_p[hm^{-1}\theta^{-1}]$ , is 1 joule  $g^{-1} (^\circ C)^{-1}$ , of  $R[ml^{-1}t^{-2}]$ , is 1 g  $cm^{-1} sec^{-2} = 1$  dyne  $cm^{-2}$ , etc.; if the chosen units are  $\theta = 1^\circ F, h = 1$  BTU,  $l = 1$  cm,  $m = 1$  lb., and  $t = 1$  sec, the unit of  $k$  is 1 BTU  $cm^{-1} sec^{-1} (^\circ F)^{-1}$ , of  $c_p$  is 1 BTU  $lb^{-1} (^\circ F)^{-1}$ , of  $R$  is 1 lb.  $cm^{-1} sec^{-2}$ , etc. The numerical values of  $F_1, F_2, F_3, K$  and  $K_s$  are the same in each case. In all cases in which nothing is said regarding units, the following equations are, as they stand, equally valid whatever the choice of units for  $\theta, h, m, l$  and  $t$ , provided the choice is consistently adhered to. In certain cases a departure from consistency is allowable, but no such departure should be made without due consideration.

## General Relations

For both free and forced convection  $W_c = \frac{2A\Delta\varphi}{D \log_e(1 + 2B/D)}$  for cylinders and tubes, and  $W_c = \frac{A}{B} \left(1 + \frac{2B}{D}\right) \Delta\varphi$  for spheres;  $D$  is the diameter of cylinder, tube, or sphere. If  $D$  is great as com-



pared with the film thickness  $B$  (say,  $D > 10B$ ), each expression reduces to  $W_c = (A\Delta\phi)/B$ , which also applies to flat surfaces. The values of  $\Delta\phi$  for Air,  $H_2$ ,  $N_2$ ,  $CO_2$  and Hg vapor, have been given by Langmuir (54). For moderate values of  $\Delta T$  (say, for  $\Delta T < 100^\circ C$ ) and when values of  $\Delta\phi$  are not available, the approximation  $\Delta\phi = k\Delta T$  is used.

For free convection,  $B = KDF_1^2 F_2^2$ ; for forced convection,  $B = KDF_1^2 F_3^2$ . In computing the values of  $F_1$ ,  $F_2$  and  $F_3$  the temperature of the fluid is to be taken as  $T_a = (T_1 + T_2)/2$  for all cases of free convection and for forced convection when  $(T_2 - T_1)$  is not great (say, for  $\Delta T < 100^\circ C$ ), and as  $T_m = \sqrt{T_1 T_2}$  for forced convection when  $(T_2 - T_1)$  is great. For ideal gases and for air  $F_1 = 1.35$ , and if  $K_0 = 1.35^\circ K$ , the expressions for  $B$  become  $B = K_0 DF_2^2$  for free, and  $B = K_0 DF_3^2$  for forced convection.

For forced convection in pipes, the film theory of convection suggests that  $W_c = ARk(\Delta T)/\nu\mu F_1^2 = ARF_1^{-2} c_p(\Delta T)/\nu$  which, when  $R$  is replaced by its empirical expression for smooth pipes (56) and  $a$  is taken as 0.5 (see Table 2), becomes  $W_c = 0.0009F_1^{1/2} \times A\rho\nu c_p(\Delta T)[1 + 84.8F_1^{0.35}]$ . This should be applicable to gases and liquids at all values of  $\nu$  above the critical velocity at which the flow becomes turbulent. For ideal gases it reduces to  $W_c = 0.00105 A\rho\nu c_p(\Delta T)[1 + 84.8F_1^{0.35}]$ .

**Special Relations for Air.**—The equations in this section assume that the unit of  $P$  is 1 atm. and that the units of the other quantities are built up from  $\theta = 1^\circ C$ ,  $h = 1$  joule,  $l = 1$  cm,  $m = 1$  g, and  $t = 1$  sec, in the manner indicated on p. 234,  $T$  and  $T_a$  being absolute Kelvin temperatures. In general they are not valid for other units. They are obtained by substituting in the equations already given the following values, applicable to air:  $\mu = 2.48 \times (10)^{-6} T^{0.744}$  g cm<sup>-1</sup> sec<sup>-1</sup>,  $k = 3.45(10)^{-6} T^{0.764}$  watt cm<sup>-1</sup>( $^\circ C$ )<sup>-1</sup>,  $\rho/\mu = 0.142(10)^6 P/T^{1.764}$  sec cm<sup>-2</sup>, and  $c_p = 1.03$  joule g<sup>-1</sup>( $^\circ C$ )<sup>-1</sup>.  $W_c = (10)^{-4} CAP^\beta(\Delta T)^\gamma/(D^3 T_a^2)$  for free, and  $W_c = (10)^{-4} CA \times (P\nu)^\beta(\Delta T)^\gamma/(D^3 T_a^2)$  for forced convection; the factor  $(10)^{-4}$  has been separated from the  $C$  for convenience in tabulation. The value of  $C$  depends upon the properties of air, the form and orientation of the body, the type of convection, and the units in which the quantities are measured. For forced convection in smooth pipes at values of  $\nu$  above the critical velocity at which the flow becomes turbulent,  $W_c = [0.000375AP\nu(\Delta T)/T_a] \times [1 + 1.35T_a^{0.614}/(PD\nu)^{0.35}]$ .

TABLE 1.—FREE CONVECTION

If  $D/B$  is great,  $W_c = A(\Delta\phi)/B$ ; if  $\Delta T$  is not great,  $\Delta\phi = k\Delta T$ . In all cases  $B = KDF_1^2 F_2^2$ ; for approximately ideal gases, such as air,  $B = K_0 DF_2^2$ . For these equations the units of  $\theta$ ,  $h$ ,  $l$ ,  $m$  and  $t$ , may be chosen as convenient, see p. 234. For air only,  $W_c = (10)^{-4} CAP^\beta(\Delta T)^\gamma/(D^3 T_a^2)$ , if  $D/B$  is great and  $\Delta T$  is not great; for this equation the units must be as follows: Unit of  $W_c = 1$  watt, of  $A = 1$  cm<sup>2</sup>, of  $P = 1$  atm., of  $\Delta T = 1^\circ C$ , of  $D = 1$  cm and of  $T_a = 1^\circ K$ . 1 watt = 1 joule/sec; 1 joule =  $10^7$  erg = 0.2389 gram calorie ( $15^\circ C$ ) = 0.0009482 BTU ( $60^\circ F$ ). In the second section of the table, numbers in column headed % are the values of  $100[W_{c(observed)} - W_{c(calculated)}]/W_{c(calculated)}$ . The serial number  $N$  serves to indicate corresponding items in the two sections of the table.

N	Type of surface	D	Gases and liquids			Gases*	
			K	a	b	K <sub>0</sub>	b
1	Cylinder, horizontal†	Diameter	2.6	0.25	0.54		
2	Cylinder, horizontal†	Diameter	2.1	0.25	0.50	2.27	0.50
3	Cylinder, vertical§	§				8.7	0.66
4	Sphere	Diameter				2.0	0.50
5	Ribbon, horizontal, plane vertical¶	Breadth**				1.46	0.50

N	Type of surface	D	Air				
			C	β	γ	δ	
1	Cylinder, horizontal†	Diameter					
2	Cylinder, horizontal†	Diameter	7.9	0.50	1.25	0.25	0.123
3	Cylinder, vertical§	§	17	0.66	1.33	0	0.415
4	Sphere	Diameter	8.8	0.50	1.25	0.25	0.123
5	Ribbon, horizontal, plane vertical¶	Breadth**	12	0.50	1.25	0.25	0.123
6	Large plane, vertical††	††	2.0	0.50	1.25	0	0
7	Large plane, horizontal, face up††	††	2.6	0.50	1.25	0	0
8	Large plane, horizontal, face down§§§	††	1.3	0.50	1.25	0	0
9	Transfer between vertical planes	††	1.2	0	1.25	0	0

N	Type of surface	Fluid	P	%	Lit.
1, 2	Small wires.....	Air	0.5 to 2.25	- 5	(46)
	Small wires, large ΔT.....	Air, H <sub>2</sub> , Hg vapor	1	- 5	(51)
	Small wires.....	Air, H <sub>2</sub> , CO <sub>2</sub>	1 to 150	± 10	(86, 87)
	Small wires in liquids††.....	C <sub>6</sub> H <sub>5</sub> N, CCl <sub>4</sub> , C <sub>2</sub> H <sub>5</sub> O <sub>2</sub> , C <sub>7</sub> H <sub>8</sub>		± 5	(26)
	Wire.....	Air	1	+ 10	(2)
	Large cylinders.....	Air	0.1 to 1	- 5	(100)
	See also (4, 5, 6, 15, 39, 54, 65, 70, 83, 88, 124)				
3	Large vertical cylinder§§.....	Air	1	± 5	(35)
	See also (51, 72)				
4	Spheres, D = 15, 20, 30 cm....	Air	1	- 10	(83)
	Sphere, D = 4 cm.....	Air	1	+ 13	(64)
	See also (4, 22, 32); data of (22) are very discordant; probably the thick coat of lampblack on the small sphere introduced an error.				
6	Disks, D = diameter = 19.1 cm   .....	Air	1	- 30	(52)
	Vertical plane¶¶.....	Air	1	+ 15	(38)
	Vertical plate***.....	Air	1	- 10	(31)
	Vertical plate†††.....	Air	1	+ 10	(67)
	Vertical cylinders†††.....	Air	1	+ 8	(36)
	See also (4, 66)				

\* Approximately ideal gases, such as air.

† Good data covering wide experimental range, gases and liquids;  $0.0003 \leq F_1 \leq 50$ .

‡ This is a convenient approximation.

§ Only observations available are for one cylinder ( $D = 17.43$  cm) in air. As  $b$  is essentially  $3/2$ ,  $DF_2^2$  is essentially independent of  $D$ , and for computational purposes  $D$  may be given any finite value, conveniently unity.

|| Data are very scanty and for air only.

¶ Rough approximation based on an average of all available data for vertical plane surfaces.

\*\* Vertical breadth.

†† Rough approximation for surfaces at least 100 cm by 100 cm and for  $T_a$  equivalent to  $75^\circ C \pm 50^\circ C$ . For the sake of obtaining an expression which is convenient for calculation, dimensional requirements have been violated. As  $\delta = 0$ ,  $D$  does not enter into the expression for  $W_c$ .

‡‡ C<sub>6</sub>H<sub>5</sub>N = aniline, C<sub>2</sub>H<sub>5</sub>O<sub>2</sub> = glycerol, C<sub>7</sub>H<sub>8</sub> = toluene.

§§  $D = 17.43$  cm.; height of cylinder = 28.8 cm.

||| Polished silver and calorized copper; vertical, face up, and face down.

¶¶ Polished aluminum, 127 cm by 127 cm.

\*\*\* Lampblack covered steel plate 24.4 cm high and 38.1 cm long.

††† Lampblack covered steel plate 80 cm high and 33.2 cm long.

‡‡‡ Lampblack covered;  $D = 17.43$  cm, heights = 4.65, 8.0, 15.2 and 28.8 cm (cf. N = 3).

§§§ No downward projecting edge. Derived from ratio to vertical surfaces (52).

|||| Transfer between two planes  $x$  cm apart ( $1.27 \leq x \leq 5.08$ ) in air at atmospheric pressure. For this range in  $x$ ,  $W_c$  is independent of  $x$  and of division into cells by horizontal partitions. Based entirely on (35).

TABLE 2.—FORCED CONVECTION

If  $D/B$  is great,  $W_c = A(\Delta\phi)/B$ , and if  $\Delta T$  is not great,  $\Delta\phi = k\Delta T$ . In all cases  $B = KDF_1^2 F_2^2$ ; for approximately ideal gases, such as air,  $B = K_0 DF_2^2$ . For these equations the units of  $\theta$ ,  $h$ ,  $l$ ,  $m$  and  $t$  may be chosen as convenient. For air only,  $W_c = (10)^{-4} CA(P\nu)^\beta(\Delta T)^\gamma/(D^3 T_a^2)$ , if  $D/B$  is great and  $\Delta T$  is not great; for this equation the units must be as follows: Unit of  $W_c = 1$  watt, of  $A = 1$  cm<sup>2</sup>, of  $P = 1$  atm., of  $\nu = 1$  cm sec<sup>-1</sup>, of  $\Delta T = 1^\circ C$ , of  $D = 1$  cm and of  $T_a = 1^\circ K$ . 1 watt = 1 joule/sec; 1 joule =  $10^7$  erg = 0.2389 g cal ( $15^\circ C$ ) = 0.0009482 BTU ( $60^\circ F$ ). In the second section of the table, numbers in column headed %



TABLE 2.—(Continued)

are the values of  $100[W_{c(\text{observed})} - W_{c(\text{calculated})}]/W_{c(\text{calculated})}$ . The serial number  $N$  serves to indicate corresponding items in the two sections of the table.

N	Type of surface	D	Gases and liquids			Gases*	
			K	a	b	$K_0$	b
1	Cylinder, horizontal, flow transverse†	Diameter	2.8	0.4	0.57	3.15	0.57
2	Cylinder, horizontal, flow transverse†	Diameter					
3	Pipe, smooth; approximate§	Diameter	60	0.50	0.83	70	0.83
4	Pipe, rough; approximate	¶	220	0.50	1.0	255	1.0
5	Large plane, smooth; approximate**	¶	220	0.50	1.0	255	1.0
6	Large plane, rough; approximate**	¶	150	0.50	1.0	175	1.0
7	Large plane, very rough¶¶; approximate**	¶	110	0.50	1.0	128	1.0

N	Type of surface	D	Air			
			C	β	δ	ε
1	Cylinder, horizontal, flow transverse†	Diameter	9.7	0.57	0.43	0.246
2	Cylinder, horizontal, flow transverse†	Diameter	8.5	0.50	0.50	0.123
3	Pipe, smooth; approximate§	Diameter	9.7	0.83	0.17	0.71
4	Pipe, rough; approximate	¶	19	1.0	0	1.0
5	Large plane, smooth; approximate**	¶	19	1.0	0	1.0
6	Large plane, rough; approximate**	¶	28	1.0	0	1.0
7	Large plane, very rough¶¶; approximate**	¶	38	1.0	0	1.0

N	Type of surface	Fluid	P	%	Lit.
1, 2	Small wires††	Air	1	-5	(47)
	Small wires	Air	1	-5	(48, 52)
	Small wires	Air	0.5 to 4	+5	(48)
	Small wires	Water; oils		±10	(29)
	Large cylinders	Air	1	-15	(49)
	Large cylinders	Air	1	±10	(34)
	See also (41, 49, 118, 119, 120, 124, 125)				
3	Brass tubes	Water		-10	(112)
	Brass tubes	Air	1	+20	(81)
	Copper tubes	Water		+10	(114, 115); cf. (112)
	Copper tubes	Water		-15	(112)
	Copper tubes	Air	1	+10	(42)
	Steel tube	Water		±30	(21)
	Tubes	Water; oils		-10	(62)
	Tubes (summary)	Water		-10	(62)
	Brass tube	Gases	1.5 to 16	±5	(72, 74)
	See also (7, 22, 28, 27, 43, 44, 58, 60, 62, 71, 94, 102, 104, 109, 117, 121, 122)				
4	Rough tube††	Water		±10	(114, 115); cf. (112)
	Tubes and ducts‡‡	Air	1	±10	(81)
	See also (50, 100)				

\* Approximately ideal gases, such as air.

† Good data covering wide experimental range in gases and liquids;  $0.00002 \leq F_1 \leq 3.0$ .

‡ Convenient approximation for large cylinders.

§ For very turbulent flow. More accurate results for gases and liquids are given by the equation  $W_0 = 0.0009F_1^{0.8} A \rho v_c (\Delta T) [1 + 84.8F_1^{0.35}]$ , which for ideal gases becomes  $W_0 = 0.00105 A \rho v_c (\Delta T) [1 + 84.8F_1^{0.35}]$ ; choice of units as for the equations involving  $K$  and  $K_0$ . For air only,  $W_0 = [0.000375 A P_0 (\Delta T) / T_0] [1 + 1.35T_0^{0.614} / (P D_0)^{0.35}]$ ; units as for the equation in C. All these equations assume that the pipe is smooth.

|| Roughness of medium sand; approximation suitable for engineering work.

¶ In this case  $b = 1$ , hence, as  $F_1 = \mu / \rho D v$ ,  $DF_1^{0.35}$  is independent of  $D$ , and for the computations for the equations in  $K$  and  $K_0$ ,  $D$  may be given any finite value, most conveniently unity. Also, as  $\delta = 0$ , the value of  $D$  is not involved in these special equations for air.

\*\* Based on average results; convenient approximation for engineering work when flow is parallel to surface and the velocity is high.

†† Data for  $v < 100$  cm/sec have not been used.

‡‡ Crossed threads approximately 0.025 cm deep.

§§ Ducts were built up of laminated iron.

¶¶ Roughness of coarse sand.

## LITERATURE

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## RADIOMETRY (HEAT AND LIGHT)

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## RADIATION CONSTANTS

W. W. COBLENTZ

For a perfect (black-body) radiator, the total hemispherical radiation (over all wave-lengths) at the absolute temperature  $T$  is  $J = \sigma T^4$ ;  $\sigma$  is known as the Stefan-Boltzmann constant of total radiation. The hemispherical radiation included in the spectral region  $(\lambda - \frac{1}{2}d\lambda)$  to  $(\lambda + \frac{1}{2}d\lambda)$  is  $J_\lambda d\lambda = C_1 \lambda^{-5} [e^{C_2/\lambda T} - 1]^{-1} d\lambda$ ;  $C_1$  and  $C_2$  are known, respectively, as the first and the second radiation constants, and  $J_\lambda$  as the monochromatic intensity of the hemispherical radiation. At each temperature  $T$ , there is a wave-length  $\lambda_m$  at which  $J_\lambda$  is a maximum;  $w (= \lambda_m T)$  is independent of  $T$ , and is known as Wien's displacement constant;  $C_2 = \alpha w$ , where  $\alpha = 4.9651$  is a pure numeric.

STEFAN-BOLTZMANN CONSTANT ( $\sigma$ ) OF TOTAL RADIATION

$J = \sigma T^4$ ;  $\sigma_o$  = observed, or reported value;  $\sigma_p$  = probable value after correcting for reflection, etc. Unit of  $\sigma = 10^{-8}$  erg  $\text{cm}^{-2} \text{sec}^{-1} (\text{°K})^{-4} = 6.451 \times 10^{-12}$  watt  $\text{in.}^{-2} (\text{°K})^{-4}$ .

Observer	Year	$\sigma_o$	$\sigma_p$	Method
Kurlbaum (12).....	1898	5.45	(?)	Bolometer
Féry (6).....	1909	6.3	(?)	Thermometer
Bauer and Moulin (2).....	1909	5.30	5.7	Thermopile
Bauer and Moulin (2).....	1910	5.7	5.7	Pyrheliometer
Todd (10).....	1909	5.48	5.48	Gas-conduction
Valentiner (20).....	1910	5.58	5.68 to 5.75	Bolometer
Féry and Drecq (7).....	1911	6.51	(?)	Thermometer
Féry and Drecq (7).....	1912	6.2	5.68	Pyrometer*
Féry and Drecq (7).....	1912	5.57		
Shakespeare (18).....	1912	5.67	5.67	Emissivity†
Gerlach (8).....	1916	5.85		Pyrheliometer†
Gerlach (8).....	1920	5.80	5.80	
Puccianti (16).....	1912	5.96	5.96	Bolometer
Puccianti (16).....		6.15	(?)	Thermometer
Westphal (27).....	1916	5.67	5.67	Emissivity†
Keene (11).....	1913	5.89	5.89	Thermometer
Coblentz (3, 4).....	1915	5.72	5.73	Pyrheliometer†

Observer	Year	$\sigma_o$	$\sigma_p$	Method
Kahanowicz (10).....	1917	5.61	5.69 to 5.73	Pyrheliometer†
Wachsmuth and Vierheller (21).....	1921	5.73	5.73	Emissivity‡
Hoffman (9).....	1923	5.76	5.76	Westphal's
Kusmann (13).....	1924	5.79	5.79	Coblentz's
Mean value.....			5.72 to 5.74	

\* Calibrated pyrometer.

† Ratio of radiance from metal to that from "black-body."

‡ Modified Ångström pyrhemometer.

§ From blackened sphere.

|| Modification of Westphal's method.

WIEN'S DISPLACEMENT CONSTANT ( $w$ ) AND THE CONSTANT ( $C_2$ ) OF SPECTRAL RADIATION

$J_\lambda = C_1 \lambda^{-5} [e^{C_2/\lambda T} - 1]^{-1}$ ;  $w = \lambda_m T$ ;  $w_o$  = observed (recorded value;  $w_c$  = value after correction for reflection, etc.;  $C'_2 = 4.9651$  and values derived from isochromatics;  $C_2$  = probable value after corrections have been applied. Note:  $\left\{ \begin{smallmatrix} 14\,200 \\ 14\,600 \end{smallmatrix} \right\}$  denote 14 200 to 14 600. Unit of  $w$  and of  $C_2 = 10^{-4}$  cm,  $\text{°K} = 1\mu$ ,  $\text{°F}$

Observer	Year	$w_o$	$w_c$	$C'_2$	$C_2$	Remarks
Paschen (15)....	1899	2 891	2 891		14 360	Fluorite prism
		2 907	2 907*			$T$ is questioned
	1900	2 921	2 894			
Lummer and Pringsheim (14).....	1900	2 879	2 879	14 290		Fluorite prism*
		2 876	2 876			
		2 940	2 882	14 310	14 300	
Warburg, et al. (21-26).....	1911			$\left\{ \begin{smallmatrix} 14\,200 \\ 14\,600 \end{smallmatrix} \right\}$		Fluorite prism
	1912			$\left\{ \begin{smallmatrix} 14\,300 \\ 14\,400 \end{smallmatrix} \right\}$		Fluorite prism
	1912			14 360		Quartz prism



WIEN'S DISPLACEMENT CONSTANT ( $w$ ) AND THE CONSTANT ( $C_1$ ) OF SPECTRAL RADIATION.—(Continued)

Observer	Year	$w_0$	$w_c$	$C_1$	$C_2$	Remarks
Warburg, <i>et al.</i> — ( <i>Cont'd.</i> ).....	1913	2 894		14 370		Quartz prism
	1915			14 250†		
	1915			{ 14 300 } 14 400	14 300	Quartz prism†
Coblentz (4, 5)...	1913	2 911		14 456		Fluorite prism
	1916	2 894		14 369		Revised‡
	1920			{ 14 311 } 14 326	14 318	Zero correction
Rubens and Michel (17)....	1921			14 300	14 300¶	
Average value...		2 885			14 320	

\* Temperature scale is questioned.

† Calibration of prism is questioned.

‡ Temperature deduced from Stefan-Boltzmann law.

§ Calibration of prism revised and preceding data recomputed.

|| Correction for zero setting of bolometer.

¶ Adopted in testing Planck's equation.

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## RADIATION FROM A PERFECT (BLACK-BODY) RADIATOR

F. E. FOWLE

The following tables, giving the hemispherical radiation ( $J$ ) and the monochromatic intensity ( $J_\lambda$ ) of the hemispherical radiation of a perfect radiator, have been computed from the values of  $C_1$  ( $=3.703 \times 10^{-5}$  erg cm<sup>-2</sup> sec<sup>-1</sup>),  $C_2$  ( $=1.433$  cm, °K), and  $\sigma$  ( $=5.709 \times 10^{-5}$  erg cm<sup>-2</sup> sec<sup>-1</sup> (°K)<sup>-4</sup>) which have been accepted for the purposes of International Critical Tables. A third table indicates how the values of  $J_\lambda$  are affected by changes in the value of  $C_2$ .

A line over a number indicates that it is negative. Thus (Table 1) at  $-270^\circ\text{C}$ ,  $J = 5.272 \times 10^{-3} = 0.005272$ .

The radiator receives radiation from surrounding bodies. If its temperature is  $T$  and if it is entirely surrounded by other perfect radiators, all at temperature  $T'$ , its resultant loss of energy by radiation (net hemispherical radiation) will be  $J_T - J_{T'}$ , per unit of area. If  $T = 1273.1^\circ\text{K}$  and  $T' = 273.1^\circ\text{K}$ , the net hemispherical radiation will be  $(1500 - 3.2) \times 10^4 = 1497 \times 10^4$  erg cm<sup>-2</sup> sec<sup>-1</sup>. (See Table 1.) Similarly for  $J_\lambda$ .

TABLE 1.—TOTAL HEMISPHERICAL RADIATION ( $J$ ) OF A PERFECT (BLACK-BODY) RADIATOR

$J = \sigma T^4 = A \times 10^n$ .  $\sigma = 5.709 \times 10^{-5}$  erg cm<sup>-2</sup> sec<sup>-1</sup> (°K)<sup>-4</sup>.  
 $T$  = absolute temperature, °K;  $t$  = centigrade temperature.  
 Unit of  $J = 1$  erg cm<sup>-2</sup> sec<sup>-1</sup> =  $2.389 \times 10^{-8}$  cal<sub>15</sub> cm<sup>-2</sup> sec<sup>-1</sup> =  $6.112 \times 10^{-10}$  BTU<sub>50</sub> in.<sup>-2</sup> sec<sup>-1</sup>.

$t$	$T$	$A$	$n$	$t$	$T$	$A$	$n$
-273	0.1	5.71	9	-180	93.1	4.289	3
-270	3.1	5.272	3	-170	103.1	6.451	3
-260	13.1	1.681	0	-160	113.1	9.342	3
-250	23.1	1.626	1	-150	123.1	1.311	4
-240	33.1	6.852	1	-140	133.1	1.792	4
-230	43.1	1.970	2	-130	143.1	2.394	4
-220	53.1	4.539	2	-120	153.1	3.137	4
-210	63.1	9.050	2	-110	163.1	4.040	4
-200	73.1	1.630	3	-100	173.1	5.126	4
-190	83.1	2.722	3	-90	183.1	6.417	4

$t$	$T$	$A$	$n$	$t$	$T$	$A$	$n$
-80	193.1	7.937	4	46	319.1	5.918	5
-70	203.1	9.714	4	48	321.1	6.070	5
-60	213.1	1.177	5	50	323.1	6.221	5
-50	223.1	1.414	5	52	325.1	6.377	5
-40	233.1	1.686	5	54	327.1	6.535	5
-30	243.1	1.994	5	56	329.1	6.697	5
-20	253.1	2.343	5	58	331.1	6.862	5
-10	263.1	2.735	5	60	333.1	7.029	5
-8	265.1	2.820	5	70	343.1	7.912	5
-6	267.1	2.906	5	80	353.1	8.875	5
-4	269.1	2.993	5	90	363.1	9.923	5
-2	271.1	3.084	5	100	373.1	1.106	6
0	273.1	3.176	5	200	473.1	2.860	6
+2	275.1	3.270	5	300	573.1	6.158	6
4	277.1	3.366	5	400	673.1	1.172	7
6	279.1	3.464	5	500	773.1	2.039	7
8	281.1	3.565	5	600	873.1	3.318	7
10	283.1	3.668	5	700	973.1	5.119	7
12	285.1	3.772	5	800	1073.1	7.570	7
14	287.1	3.879	5	900	1173.1	1.081	8
16	289.1	3.988	5	1 000	1273.1	1.500	8
18	291.1	4.100	5	1 500	1773.1	5.643	8
20	293.1	4.213	5	2 000	2273.1	1.524	9
22	295.1	4.330	5	3 000	3273.1	6.552	9
24	297.1	4.448	5	4 000	4273.1	1.903	10
26	299.1	4.569	5	5 000	5273.1	4.414	10
28	301.1	4.692	5	6 000	6273.1	8.841	10
30	303.1	4.818	5	7 000	7273.1	1.598	11
32	305.1	4.947	5	8 000	8273.1	2.674	11
34	307.1	5.078	5	9 000	9273.1	4.221	11
36	309.1	5.211	5	10 000	10273.1	6.358	11
38	311.1	5.348	5	15 000	15273.1	3.106	12
40	313.1	5.486	5	20 000	20273.1	9.644	12
42	315.1	5.628	5	25 000	25273.1	2.329	13
44	317.1	5.772	5				



TABLE 2.—MONOCHROMATIC INTENSITY ( $J_\lambda$ ) OF HEMISPHERICAL RADIATION OF PERFECT (BLACK-BODY) RADIATOR

$J_\lambda = C_1 \lambda^{-5} [e^{C_2/\lambda T} - 1]^{-1}$ ,  $T$  = absolute temperature,  $\lambda$  = wave-length of the radiation. Total hemispherical radiation in range  $\lambda_1$  to  $\lambda_2$  is  $\int_{\lambda_1}^{\lambda_2} J_\lambda d\lambda$ . If  $C_1 = 3.703 \times 10^{-5}$  erg cm<sup>2</sup> sec<sup>-1</sup>,  $C_2 = 1.433$  cm, °K and unit of  $d\lambda = 1$  cm, then  $J_\lambda = A \times 10^n$  erg cm<sup>-2</sup> sec<sup>-1</sup>, where  $A$  and  $n$  have the values tabulated below. 1 erg cm<sup>-2</sup> sec<sup>-1</sup> =  $2.389 \times 10^{-8}$  cal<sub>15</sub> cm<sup>-2</sup> sec<sup>-1</sup> =  $6.118 \times 10^{-10}$  BTU<sub>59</sub> in.<sup>-2</sup> sec<sup>-1</sup>  $\times$  (dλ)<sub>cm</sub><sup>-1</sup>, where (dλ)<sub>cm</sub> indicates that unit of  $d\lambda = 1$  cm. For each  $T$  the maximum value of  $J_\lambda$  is printed in bold face. In column  $\lambda$ , unit of  $\lambda = 1\mu = 10^4 \text{Å} = 10^{-4}$  cm;  $T$  = absolute temperature, °K.

$T$	25		50		75		100		125		150		175		200		225		250	
$\lambda$	$A$	$n$	$A$	$n$	$A$	$n$	$A$	$n$	$A$	$n$	$A$	$n$	$A$	$n$	$A$	$n$	$A$	$n$	$A$	$n$
1.0	3.7	234	1.3	109	4.1	68	2.2	47	6.0	35	1.2	26	1.0	20	2.8	16	8.1	13	4.7	10
1.5	4.9	152	4.9	69	2.3	41	1.6	27	3.1	19	1.1	13	1.0	9	8.8	7	1.8	4	1.23	2
2.0	3.9	111	6.8	49	3.8	28	8.8	18	1.5	11	2.1	7	1.9	4	3.2	2	1.72	0	4.2	1
2.5	9.9	87	6.4	37	2.4	20	4.8	12	4.6	7	9.6	4	2.27	1	1.36	1	3.26	2	4.2	3
3.0	1.6	70	5.0	29	3.3	15	2.7	8	3.8	4	2.26	1	2.12	1	6.5	2	9.2	3	7.7	4
3.5	5.1	59	1.9	23	1.4	11	1.17	5	4.2	2	9.8	0	4.8	2	9.1	3	8.8	4	5.4	5
4	2.1	50	2.8	19	6.5	9	1.00	3	1.29	0	1.54	2	4.6	3	6.0	4	4.40	5	2.16	6
5	1.9	38	1.5	13	3.0	5	4.2	1	1.30	2	5.9	3	9.1	4	7.1	5	3.47	6	1.25	7
6	1.6	30	8.6	10	7.1	3	2.03	1	2.40	3	5.8	4	5.62	5	3.11	6	1.18	7	3.38	7
7	6.1	25	3.7	7	3.1	1	2.84	2	1.70	4	2.60	5	1.83	6	7.87	6	2.46	7	6.13	7
8	8.6	21	3.1	5	4.8	0	1.88	3	6.76	4	7.4	5	4.05	6	1.46	7	3.95	7	8.75	7
9	1.4	17	9.3	4	3.8	1	7.6	3	1.84	5	1.55	6	7.02	6	2.19	7	5.30	7	1.08	8
10	4.7	15	1.32	2	1.87	2	2.21	4	3.89	5	2.63	6	1.03	7	2.87	7	6.36	7	1.204	8
12	2.7	11	6.3	1	1.81	3	9.7	4	1.06	6	5.20	6	1.62	7	3.81	7	7.42	7	1.264	8
14	1.1	8	8.9	0	8.1	3	2.46	5	1.92	6	7.50	6	1.99	7	4.15	7	7.36	7	1.167	8
16	9.8	7	5.9	1	2.30	4	4.56	5	2.73	6	9.02	6	2.13	7	4.06	7	6.72	7	1.011	8
18	2.90	5	2.39	2	4.84	4	6.84	5	3.36	6	9.76	6	2.10	7	3.73	7	5.87	7	8.47	7
20	4.14	4	6.9	2	8.2	4	8.95	5	3.76	6	9.83	6	1.96	7	3.31	7	5.00	7	6.99	7
25	4.18	2	4.00	3	1.82	5	1.233	6	3.91	6	8.49	6	1.490	7	2.289	7	3.22	7	4.26	7
30	7.68	1	1.08	4	2.62	5	1.295	6	3.41	6	6.58	6	1.063	7	1.525	7	2.071	7	2.647	7
40	2.16	1	2.80	4	3.07	5	1.035	6	2.18	6	3.619	6	5.36	6	7.24	6	9.24	6	1.133	7
50	1.25	2	3.85	4	2.65	5	1.15	5	1.331	6	2.058	6	2.859	6	3.713	6	4.60	6	5.52	6
75	7.5	2	3.50	4	1.327	5	2.712	5	4.33	5	6.06	5	7.89	5	9.77	5	1.167	6	1.362	6
100	1.20	3	2.24	4	6.43	4	1.160	5	1.725	5	2.316	5	2.920	5	3.536	5	4.158	5	4.777	5
$T$	273		275		300		325		350		373		375		400		500		600	
$\lambda$	$A$	$n$	$A$	$n$	$A$	$n$	$A$	$n$	$A$	$n$	$A$	$n$	$A$	$n$	$A$	$n$	$A$	$n$	$A$	$n$
1.0	5.9	8	8.8	8	6.7	6	2.6	4	6.1	3	7.6	2	9.4	2	1.03	1	1.32	3	1.58	5
1.5	3.1	1	4.0	1	7.2	0	8.4	1	6.8	2	3.7	3	4.2	3	2.08	4	2.46	6	5.94	7
2.0	4.6	2	5.6	2	4.9	3	3.10	4	1.51	5	5.3	5	5.8	5	1.93	6	6.92	7	7.55	8
2.5	2.88	4	3.37	4	1.91	5	8.3	5	2.92	6	8.0	6	8.8	6	2.27	7	4.00	8	2.69	9
3.0	3.84	5	4.36	5	1.86	6	6.3	6	1.80	7	4.16	7	4.56	7	9.94	7	1.08	9	5.32	9
3.5	2.16	6	2.41	6	8.3	6	2.38	7	5.85	7	1.20	8	1.27	8	2.52	8	1.96	9	7.68	9
4	7.2	6	7.9	6	2.36	7	5.90	7	1.30	8	2.44	8	2.57	8	4.66	8	2.80	9	9.25	9
5	3.26	7	3.54	7	8.4	7	1.75	8	3.30	8	5.45	8	5.68	8	9.17	8	3.85	9	1.006	10
6	7.56	7	8.05	7	1.66	8	3.07	8	5.19	8	7.90	8	8.18	8	1.218	9	4.04	9	9.07	9
7	1.22	8	1.29	8	2.40	8	4.06	8	6.37	8	9.15	8	9.42	8	1.327	9	3.73	9	7.51	9
8	1.60	8	1.68	8	2.89	8	4.59	8	6.81	8	9.36	8	9.61	8	1.298	9	3.23	9	6.01	9
9	1.84	8	1.92	8	3.12	8	4.71	8	6.70	8	8.90	8	9.11	8	1.194	9	2.710	9	4.75	9
10	1.96	8	2.03	8	3.14	8	4.56	8	6.28	8	8.12	8	8.30	8	1.060	9	2.236	9	3.71	9
12	1.90	8	1.96	8	2.83	8	3.87	8	5.07	8	6.32	8	6.43	8	7.92	8	1.489	9	2.36	9
14	1.660	8	1.706	8	2.35	8	3.08	8	3.90	8	4.73	8	4.81	8	5.78	8	1.020	9	1.530	9
16	1.381	8	1.414	8	1.880	8	2.40	8	2.96	8	3.52	8	3.53	8	4.22	8	7.07	8	1.024	9
18	1.122	8	1.147	8	1.484	8	1.851	8	2.246	8	2.632	8	2.664	8	3.103	8	5.01	8	7.076	8
20	9.04	7	9.24	7	1.158	8	1.434	8	1.716	8	1.986	8	2.011	8	2.317	8	3.627	8	5.032	8
25	5.29	7	5.39	7	6.59	7	7.85	7	9.15	7	1.039	8	1.051	8	1.188	8	1.767	8	2.371	8
30	3.206	7	3.255	7	3.892	7	4.550	7	5.23	7	5.865	7	5.920	7	6.626	7	9.53	7	1.252	8
40	1.332	7	1.349	7	1.572	7	1.799	7	2.028	7	2.242	7	2.262	7	2.496	7	3.453	7	4.426	7
50	6.379	6	6.458	6	7.409	6	8.37	6	9.35	6	1.025	7	1.033	7	1.132	7	1.535	7	1.935	7
75	1.544	6	1.557	6	1.754	6	1.952	6	2.151	6	2.335	6	2.351	6	2.551	6	3.357	6	4.166	6
100	5.366	5	5.416	5	6.050	5	6.683	5	7.32	5	7.906	5	7.958	5	8.60	5	1.110	6	1.374	6



## INTERNATIONAL CRITICAL TABLES

TABLE 2.—(Continued)

T	800		1 000		1 200		1 400		1 600		1 800		2 000		2 200		2 400		2 600		2 800	
$\lambda$	A	n	A	n	A	n	A	n	A	n	A	n	A	n	A	n	A	n	A	n	A	n
0.10	6	58	2.1	42	5.1	32	1.3	24	4.7	19	1.0	14	2.8	11	1.9	8	4.3	6	4.3	4	2.2	2
0.20	1.5	20	9	13	1.4	7	6.9	4	4.1	1	6.0	1	3.2	3	8.3	4	1.25	6	1.24	7	8.9	7
0.30	1.8	8	2.7	3	7.9	0	2.3	3	1.65	5	4.5	6	6.5	7	5.7	8	3.46	9	1.60	10	5.9	10
0.40	1.28	2	1.00	2	3.9	4	2.8	6	6.8	7	8.2	8	6.0	9	3.08	10	1.19	11	3.75	11	1.00	12
0.41	3.4	2	2.1	2	7.2	4	4.6	6	1.04	8	1.18	9	8.2	9	4.01	10	1.52	11	4.65	11	1.22	12
0.42	8.5	2	4.3	2	1.27	5	7.4	6	1.56	8	1.65	9	1.10	10	5.2	10	1.90	11	5.6	11	1.45	12
0.43	2.04	1	8.5	2	2.19	5	1.16	7	2.26	8	2.30	9	1.46	10	6.6	10	2.35	11	6.8	11	1.71	12
0.44	4.7	1	1.61	3	3.7	5	1.78	7	3.24	8	3.10	9	1.91	10	8.4	10	2.8	11	8.2	11	2.00	12
0.45	1.04	0	3.0	3	6.0	5	2.67	7	4.6	8	4.17	9	2.45	10	1.04	11	3.47	11	9.6	11	2.31	12
0.46	2.2	0	5.3	3	9.5	5	3.9	7	6.3	8	5.46	9	3.09	10	1.27	11	4.15	11	1.13	12	2.64	12
0.47	4.5	0	9.2	3	1.49	6	5.6	7	8.5	8	7.2	9	3.87	10	1.54	11	4.93	11	1.30	12	3.01	12
0.48	9.1	0	1.57	4	2.28	6	8.0	7	1.14	9	9.2	9	4.77	10	1.86	11	5.75	11	1.50	12	3.41	12
0.49	1.74	1	2.60	4	3.42	6	1.11	8	1.51	9	1.15	10	5.9	10	2.22	11	6.7	11	1.71	12	3.82	12
0.50	3.3	1	4.2	4	5.0	6	1.53	8	1.97	9	1.44	10	7.1	10	2.60	11	7.7	11	1.94	12	4.23	12
0.51	6.0	1	6.7	4	7.3	6	2.08	8	2.54	9	1.79	10	8.5	10	3.05	11	8.8	11	2.17	12	4.73	12
0.52	1.06	2	1.05	5	1.04	7	2.74	8	3.22	9	2.20	10	1.01	11	3.52	11	1.01	12	2.43	12	5.18	12
0.53	1.85	2	1.60	5	1.45	7	3.60	8	4.07	9	2.65	10	1.19	11	4.07	11	1.13	12	2.69	12	5.67	12
0.54	3.16	2	2.40	5	2.02	7	4.7	8	5.1	9	3.18	10	1.40	11	4.66	11	1.27	12	2.97	12	6.17	12
0.55	5.3	2	3.50	5	2.74	7	6.1	8	6.3	9	3.80	10	1.62	11	5.30	11	1.42	12	3.27	12	6.69	12
0.56	8.6	2	5.2	5	3.7	7	7.7	8	7.6	9	4.50	10	1.86	11	5.98	11	1.58	12	3.58	12	7.22	12
0.57	1.38	3	7.5	5	5.0	7	9.8	8	9.2	9	5.29	10	2.14	11	6.68	11	1.74	12	3.89	12	7.8	12
0.58	2.19	3	1.05	6	6.4	7	1.22	9	1.11	10	6.2	10	2.44	11	7.5	11	1.91	12	4.21	12	8.3	12
0.59	3.38	3	1.46	6	8.4	7	1.51	9	1.33	10	7.1	10	2.76	11	8.3	11	2.09	12	4.54	12	8.9	12
0.60	5.2	3	2.02	6	1.08	8	1.86	9	1.56	10	8.2	10	3.10	11	9.2	11	2.27	12	4.89	12	9.4	12
0.61	7.8	3	2.76	6	1.38	8	2.26	9	1.85	10	9.4	10	3.47	11	1.01	12	2.46	12	5.23	12	1.00	13
0.62	1.15	4	3.70	6	1.75	8	2.73	9	2.15	10	1.07	11	3.87	11	1.10	12	2.66	12	5.57	12	1.05	13
0.63	1.68	4	4.96	6	2.18	8	3.27	9	2.50	10	1.21	11	4.29	11	1.21	12	2.86	12	5.93	12	1.11	13
0.64	2.41	4	6.5	6	2.71	8	3.92	9	2.88	10	1.36	11	4.74	11	1.31	12	3.06	12	6.28	12	1.16	13
0.65	3.44	4	8.5	6	3.36	8	4.61	9	3.31	10	1.53	11	5.21	11	1.42	12	3.28	12	6.64	12	1.22	13
0.66	4.83	4	1.10	7	4.08	8	5.5	9	3.78	10	1.71	11	5.71	11	1.53	12	3.49	12	6.99	12	1.27	13
0.67	6.7	4	1.41	7	5.0	8	6.4	9	4.30	10	1.90	11	6.22	11	1.64	12	3.70	12	7.34	12	1.32	13
0.68	9.3	4	1.80	7	6.0	8	7.4	9	4.86	10	2.10	11	6.76	11	1.76	12	3.92	12	7.7	12	1.37	13
0.69	1.25	5	2.27	7	7.2	8	8.6	9	5.5	10	2.31	11	7.32	11	1.88	12	4.14	12	8.0	12	1.42	13
0.70	1.69	5	2.84	7	8.6	8	9.9	9	6.1	10	2.53	11	7.91	11	2.00	12	4.36	12	8.4	12	1.47	13
0.71	2.26	5	3.52	7	1.02	9	1.13	10	6.8	10	2.77	11	8.52	11	2.13	12	4.57	12	8.7	12	1.52	13
0.72	3.00	5	4.35	7	1.21	9	1.28	10	7.6	10	3.02	11	9.12	11	2.26	12	4.79	12	9.1	12	1.57	13
0.73	3.96	5	5.3	7	1.40	9	1.45	10	8.4	10	3.28	11	9.76	11	2.38	12	5.01	12	9.4	12	1.61	13
0.74	5.14	5	6.5	7	1.64	9	1.64	10	9.2	10	3.55	11	1.04	12	2.51	12	5.23	12	9.7	12	1.66	13
0.75	6.6	5	7.9	7	1.90	9	1.84	10	1.02	11	3.83	11	1.11	12	2.64	12	5.44	12	1.00	13	1.70	13
0.76	8.5	5	9.4	7	2.19	9	2.06	10	1.11	11	4.12	11	1.18	12	2.77	12	5.66	12	1.04	13	1.74	13
0.77	1.08	6	1.13	8	2.52	9	2.31	10	1.22	11	4.42	11	1.24	12	2.90	12	5.87	12	1.07	13	1.78	13
0.78	1.36	6	1.34	8	2.90	9	2.56	10	1.32	11	4.74	11	1.32	12	3.03	12	6.08	12	1.10	13	1.82	13
0.79	1.72	6	1.61	8	3.26	9	2.84	10	1.44	11	5.06	11	1.39	12	3.16	12	6.28	12	1.12	13	1.85	13
0.80	2.13	6	1.88	8	3.71	9	3.14	10	1.55	11	5.39	11	1.46	12	3.29	12	6.49	12	1.15	13	1.89	13
0.90	1.43	7	7.6	8	1.08	10	7.21	10	2.99	11	9.03	11	2.19	12	4.51	12	8.25	12	1.38	13	2.14	13
1.00	6.17	7	2.21	9	2.41	10	1.33	11	4.78	11	1.29	12	2.86	12	5.50	12	9.47	12	1.50	13	2.23	13
1.50	3.18	9	3.46	10	1.70	11	5.30	11	1.25	12	2.43	12	4.15	12	6.44	12	9.27	12	1.209	13	1.662	13
2.00	1.49	10	8.96	10	2.96	11	6.98	11	1.33	12	2.20	12	3.31	12	4.63	12	6.16	12	7.85	12	9.71	12
2.50	2.94	10	1.23	11	3.22	11	6.43	11	1.08	12	1.64	12	2.29	12	3.03	12	3.79	12	4.70	12	5.62	12
3.00	3.90	10	1.29	11	2.90	11	5.20	11	8.11	11	1.15	12	1.52	12	1.961	12	2.412	12	2.888	12	3.38	12
4.00	4.16	10	1.04	11	1.93	11	3.03	11	4.31	11	5.72	11	7.24	11	8.83	11	1.048	12	1.219	12	1.395	12
5.00	3.39	10	7.15	10	1.19	11	1.76	11	2.37	11	3.03	11	3.71	11	4.421	11	5.15	11	5.89	11	6.64	11
10.00	7.41	9	1.16	10	1.61	10	2.08	10	2.56	10	3.04	10	3.54	10	4.033	10	4.53	10	5.04	10	5.54	10



TABLE 2.—(Continued)

$T$	3 000		4 000		5 000		6 000		7 000		8 000		9 000		10 000		15 000		20 000		25 000	
$\lambda$	$A$	$n$	$A$	$n$	$A$	$n$	$A$	$n$	$A$	$n$	$A$	$n$	$A$	$n$	$A$	$n$	$A$	$n$	$A$	$n$	$A$	$n$
0.10	6.7	1	1.02	5	1.32	8	1.57	10	4.8	11	6.2	12	4.51	13	2.21	14	2.63	16	2.86	17	1.204	18
0.20	4.9	8	1.92	11	6.9	12	7.5	13	4.1	14	1.49	15	4.04	15	8.95	15	9.84	16	3.31	17	6.98	17
0.30	1.86	11	9.9	12	1.08	14	5.32	14	1.66	15	3.90	15	7.59	15	1.296	16	6.58	16	1.525	17	2.647	17
0.40	2.36	12	4.66	13	2.80	14	9.25	14	2.18	15	4.16	15	6.88	15	1.034	16	3.62	16	7.24	16	1.133	17
0.41	2.79	12	5.13	13	2.95	14	9.46	14	2.18	15	4.10	15	6.72	15	1.000	16	3.44	16	6.74	16	1.049	17
0.42	3.26	12	5.60	13	3.08	14	9.68	14	2.18	15	4.04	15	6.54	15	9.66	15	3.25	16	6.29	16	9.71	16
0.43	3.77	12	6.06	13	3.21	14	9.79	14	2.18	15	3.97	15	6.37	15	9.32	15	3.06	16	5.86	16	9.02	16
0.44	4.33	12	6.54	13	3.34	14	9.91	14	2.16	15	3.90	15	6.19	15	9.00	15	2.89	16	5.48	16	8.38	16
0.45	4.93	12	7.00	13	3.45	14	9.98	14	2.14	15	3.82	15	6.01	15	8.67	15	2.732	16	5.13	16	7.79	16
0.46	5.56	12	7.46	13	3.54	14	1.006	15	2.12	15	3.74	15	5.83	15	8.35	15	2.578	16	4.80	16	7.26	16
0.47	6.25	12	7.91	13	3.64	14	1.010	15	2.10	15	3.66	15	5.64	15	8.04	15	2.435	16	4.49	16	6.76	16
0.48	6.93	12	8.35	13	3.72	14	1.011	15	2.07	15	3.57	15	5.47	15	7.73	15	2.300	16	4.21	16	6.32	16
0.49	7.65	12	8.77	13	3.79	14	1.010	15	2.04	15	3.48	15	5.29	15	7.44	15	2.176	16	3.96	16	5.90	16
0.50	8.41	12	9.16	13	3.85	14	1.008	15	2.01	15	3.39	15	5.12	15	7.15	15	2.058	16	3.714	16	5.52	16
0.51	9.18	12	9.56	13	3.91	14	1.002	15	1.97	15	3.30	15	4.95	15	6.87	15	1.947	16	3.488	16	5.17	16
0.52	9.99	12	9.92	13	3.95	14	9.96	14	1.94	15	3.21	15	4.78	15	6.61	15	1.846	16	3.282	16	4.84	16
0.53	1.08	13	1.03	14	3.98	14	9.89	14	1.90	15	3.12	15	4.62	15	6.35	15	1.746	16	3.089	16	4.54	16
0.54	1.16	13	1.06	14	4.01	14	9.79	14	1.86	15	3.03	15	4.46	15	6.10	15	1.657	16	2.910	16	4.266	16
0.55	1.24	13	1.09	14	4.04	14	9.72	14	1.82	15	2.95	15	4.31	15	5.87	15	1.572	16	2.745	16	4.009	16
0.56	1.33	13	1.12	14	4.05	14	9.58	14	1.78	15	2.86	15	4.16	15	5.64	15	1.492	16	2.589	16	3.771	16
0.57	1.41	13	1.15	14	4.06	14	9.46	14	1.745	15	2.78	15	4.01	15	5.43	15	1.417	16	2.447	16	3.547	16
0.58	1.50	13	1.18	14	4.06	14	9.34	14	1.703	15	2.70	15	3.87	15	5.21	15	1.347	16	2.313	16	3.345	16
0.59	1.58	13	1.20	14	4.05	14	9.20	14	1.665	15	2.61	15	3.74	15	5.00	15	1.279	16	2.187	16	3.154	16
0.60	1.66	13	1.22	14	4.05	14	9.06	14	1.623	15	2.53	15	3.60	15	4.80	15	1.217	16	2.071	16	2.978	16
0.61	1.74	13	1.24	14	4.03	14	8.92	14	1.584	15	2.46	15	3.48	15	4.62	15	1.158	16	1.961	16	2.812	16
0.62	1.82	13	1.26	14	4.01	14	8.77	14	1.547	15	2.381	15	3.36	15	4.45	15	1.103	16	1.858	16	2.660	16
0.63	1.90	13	1.28	14	3.99	14	8.62	14	1.507	15	2.308	15	3.24	15	4.28	15	1.049	16	1.762	16	2.516	16
0.64	1.98	13	1.29	14	3.96	14	8.47	14	1.469	15	2.235	15	3.13	15	4.11	15	9.99	15	1.671	16	2.381	16
0.65	2.06	13	1.30	14	3.93	14	8.31	14	1.429	15	2.165	15	3.01	15	3.96	15	9.53	15	1.587	16	2.256	16
0.66	2.13	13	1.30	14	3.91	14	8.16	14	1.393	15	2.099	15	2.91	15	3.81	15	9.10	15	1.508	16	2.139	16
0.67	2.20	13	1.31	14	3.86	14	7.99	14	1.357	15	2.032	15	2.81	15	3.66	15	8.67	15	1.433	16	2.027	16
0.68	2.27	13	1.32	14	3.82	14	7.84	14	1.319	15	1.970	15	2.713	15	3.52	15	8.28	15	1.363	16	1.925	16
0.69	2.34	13	1.325	14	3.78	14	7.68	14	1.286	15	1.908	15	2.614	15	3.39	15	7.91	15	1.297	16	1.829	16
0.70	2.40	13	1.327	14	3.74	14	7.51	14	1.250	15	1.848	15	2.525	15	3.26	15	7.55	15	1.235	16	1.737	16
0.71	2.46	13	1.330	14	3.69	14	7.37	14	1.217	15	1.790	15	2.437	15	3.14	15	7.23	15	1.178	16	1.653	16
0.72	2.52	13	1.332	14	3.64	14	7.20	14	1.184	15	1.735	15	2.356	15	3.03	15	6.91	15	1.123	16	1.573	16
0.73	2.58	13	1.329	14	3.59	14	7.05	14	1.151	15	1.682	15	2.274	15	2.918	15	6.61	15	1.071	16	1.497	16
0.74	2.63	13	1.329	14	3.54	14	6.90	14	1.121	15	1.627	15	2.195	15	2.812	15	6.33	15	1.022	16	1.428	16
0.75	2.68	13	1.326	14	3.49	14	6.74	14	1.089	15	1.561	15	2.120	15	2.710	15	6.06	15	9.76	15	1.360	16
0.76	2.73	13	1.321	14	3.44	14	6.59	14	1.059	15	1.527	15	2.047	15	2.610	15	5.80	15	9.32	15	1.297	16
0.77	2.77	13	1.317	14	3.39	14	6.44	14	1.030	15	1.482	15	1.979	15	2.518	15	5.56	15	8.91	15	1.238	16
0.78	2.82	13	1.313	14	3.34	14	6.30	14	1.003	15	1.436	15	1.916	15	2.431	15	5.34	15	8.52	15	1.183	16
0.79	2.86	13	1.304	14	3.28	14	6.15	14	9.75	14	1.391	15	1.850	15	2.342	15	5.12	15	8.15	15	1.129	16
0.80	2.89	13	1.298	14	3.23	14	6.01	14	9.48	14	1.348	15	1.788	15	2.261	15	4.91	15	7.80	15	1.079	16
0.90	3.12	13	1.193	14	2.71	14	4.75	14	7.19	14	9.93	14	1.289	15	1.602	15	3.316	15	5.15	15	7.04	15
1.00	3.15	13	1.059	14	2.235	14	3.70	14	5.49	14	7.413	14	9.46	14	1.161	15	2.316	15	3.537	15	4.784	15
1.50	2.11	13	4.88	13	8.47	13	1.245	14	1.672	14	2.120	14	2.578	14	3.049	14	5.476	14	7.96	14	1.048	15
2.00	1.162	13	2.316	13	3.626	13	5.03	13	8.49	13	7.99	13	9.51	13	1.105	14	1.889	14	2.687	14	3.487	14
2.50	6.59	12	1.187	13	1.768	13	2.372	13	2.990	13	3.622	13	4.258	13	4.899	13	8.15	13	1.143	14	1.471	14
3.00	3.892	12	6.63	12	9.53	12	1.252	13	1.558	13	1.862	13	2.176	13	2.489	13	4.065	13	5.651	13	7.24	13
4.00	1.572	12	2.497	12	3.454	12	4.419	12	5.410	12	6.40	12	7.40	12	8.40	12	1.341	13	1.844	13	2.348	13
5.00	7.41	11	1.132	12	1.531	12	1.935	12	2.343	12	2.752	12	3.160	12	3.572	12	5.626	12	7.70	12	9.76	12
10.00	6.05	10	8.60	10	1.116	11	1.373	11	1.630	11	1.888	11	2.144	11	2.404	11	3.666	11	4.988	11	6.277	11



TABLE 3.—EFFECT OF A CHANGE IN  $C_2$

If  $dJ_\lambda$  = increase produced in  $J_\lambda$  by an infinitesimal increase ( $dC_2$ ) in  $C_2$ , then  $(dJ_\lambda)/J_\lambda = -K(dC_2)/C_2$ ; for the units of Table 2 and  $C_2 = 1.433$  cm, °K,  $K$  has the appropriate value tabulated below. *Example:* If  $C_2 = 1.433$  cm, °K, then, at 300°K and  $\lambda = 2\mu$ ,  $J_\lambda = 4900$  (Table 2) and  $K = 24$  (Table 3); hence, if  $C_2 = 1.434$ ,  $(dC_2)/C_2 = 0.0007$ ,  $(dJ_\lambda)/J_\lambda = -24(0.0007) = -0.017$ ,  $dJ_\lambda = -(0.017)(4900) = -83$  and  $J_\lambda = 4900 - 83 = 4817$ . Unit of  $\lambda = 1\mu = 10^{-4}$  cm;  $T$  = absolute temperature, °K.

$\lambda$	1	2	3	4	5	6	7	8	9	10	15	20	100	$\lambda$	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	2	3	4	5
$T$	$K$													$T$	$K$													
25	573	287	191	143	115	96	82	72	64	57	34	29	6	800	179	90	60	45	36	30	26	22	20	18	9	6	4	4
50	287	143	96	72	57	48	41	36	32	29	17	14	3	1 000	143	72	48	36	29	24	20	18	16	14	7	5	3	3
75	191	96	64	48	38	32	27	24	21	19	11	10	2	1 500	96	48	32	24	20	16	14	12	10	10	5	3	3	3
100	143	72	48	36	29	24	20	18	16	14	8	7	2	2 000	72	36	24	18	14	12	10	9	8	7	5	2	2	2
200	72	36	24	18	14	12	10	9	8	7	4	3	1	3 000	48	24	15	12	10	8	7	6	6	5	3	2	1	1
250	57	29	19	14	11	10	8	7	6	6	3	3	1	4 000	36	18	12	9	7	6	5	4	4	3	2	1	1	1
300	47	24	16	12	10	8	7	6	6	5	3	3	1	5 000	29	14	8	7	6	5	4	3	3	3	2	1	1	1
350	40	20	13	11	8	7	6	5	4	4	3	2	1	7 500	20	9	6	5	4	3	3	3	2	2	1	1	1	1
400	36	18	12	9	7	6	5	4	4	3	3	2	1	10 000	14	7	5	3	3	3	2	2	2	2	1	1	1	1
500	29	14	10	7	6	5	4	3	3	3	2	2	1	20 000	7	3	3	2	2	1	1	1	1	1	1	1	1	1
600	24	12	8	6	5	4	3	3	3	3	2	1	1	25 000	6	3	2	2	1	1	1	1	1	1	1	1	1	1

THERMAL RADIATION FROM MATERIALS AND SELECTED SOURCES OF RADIATION

W. W. COBLENTZ

For radiation from a "black-body," see p. 238.

At wave-length  $\lambda$ , the monochromatic intensity of the normal radiation of a body is  $J_{\lambda\lambda}$ , where  $J_{\lambda\lambda}d\lambda$  = amount of radiant energy, having wave-lengths lying between  $(\lambda - 0.5d\lambda)$  and  $(\lambda + 0.5d\lambda)$ , which the body emits in a direction perpendicular to its radiating surface per unit of time, of surface, and of solid angle;  $J_n = \int_0^\infty J_{\lambda\lambda}d\lambda$  is the normal intensity of the total radiation of the body. If the emission satisfies Lambert's law, as is the case for the substances here considered, the hemispherical intensity of the total radiation is  $J = \pi J_n$  = total emission per unit of time and of area, and the monochromatic intensity of the hemispherical radiation is  $J_\lambda = \pi J_{\lambda\lambda}$ . If the corresponding quantities for a perfect radiator (black-body) at the same temperature be indicated by  $J_b$  and  $J_{b\lambda}$ , and if  $e_\lambda = J_\lambda/J_{b\lambda}$  and  $e_t = J/J_b$ , then  $e_\lambda$  and  $e_t$  are, respectively, the monochromatic and the total emissivity of the body. If  $J_c$  = value of the hemispherical intensity of the total radiation of a black-body at such a temperature that it has the same color as that of the body considered,  $e_c = J/J_c$  is the color emissivity of the body; and if  $e_v = (\int_{\lambda_1}^{\lambda_2} J_{\lambda\lambda}d\lambda) \div (\int_{\lambda_1}^{\lambda_2} J_{b\lambda}d\lambda)$ , where  $\lambda_1$  and  $\lambda_2$  mark the limits of visible spectrum (about  $0.4\mu$  and  $0.75\mu$ ),  $e_v$  is the visible emissivity. The Crova wave-length  $\lambda_c$  that at which  $\frac{1}{J_\lambda} \frac{dJ_\lambda}{dT} = \frac{1}{J} \frac{dJ}{dT}$ . Usually the quantities directly observed are  $J_{\lambda\lambda}$  and  $J_n$ , and  $J_\lambda$  and  $J$  are computed from them on the assumption that Lambert's law is valid.

TABLE 1.—MONOCHROMATIC EMISSIVITY ( $e_\lambda$ ) OF ELEMENTARY SUBSTANCES AND OXIDES: TEMPERATURE OF FUSION(1)

Assumes  $C_2 = 14\,450$  micron °C. A micropyrometer was used.  $s$  = solid,  $l$  = liquid. Unit of  $e_\lambda = 0.01 = 1\%$ ; of  $\lambda = 1\mu = 0.001$  mm =  $10000\text{ \AA}$ .

$\lambda =$	0.55		0.65		$\lambda =$	0.55		0.65	
Symbol	$s$	$l$	$s$	$l$	Symbol	$s$	$l$	$s$	$l$
Ag*.....	<35	<35	4	7	Cr.....	53		39	39
Au*.....	<38	<38	14	22	Cu*.....	38	36	10	15
Be.....	61	81	61	61	Er.....		30	55	38
Cb.....	61		49	40	Fe.....			37	37
Co.....			36	37	Ir.....			30	

$\lambda =$	0.55		0.65		$\lambda =$	0.55		0.65	
Symbol	<i>s</i>	<i>l</i>	<i>s</i>	<i>l</i>	Symbol	<i>s</i>	<i>l</i>	<i>s</i>	<i>l</i>
Mn.....			59	59	BeO.....			37	
Mo*.....			43	40	CbO <sub>2</sub> .....			71	
Ni.....	44	46	36	37	Co <sub>2</sub> O <sub>4</sub> .....			77	63
Pd.....	38		33	37	Cr <sub>2</sub> O <sub>3</sub> .....			60	
Pt*.....	38		33	38	Fe <sub>2</sub> O <sub>4</sub> .....			63	53
Rh.....			29	30	Mn <sub>2</sub> O <sub>4</sub> ....				47
Th.....	36		36	40	NiO.....			89	68
Ti.....	75	75	63	65	ThO <sub>2</sub> .....			57	69
U.....	77		54	34	TiO <sub>2</sub> .....			52	51
V.....	29		35	32	U <sub>2</sub> O <sub>3</sub> .....			30	31
W*.....			39		V <sub>2</sub> O <sub>5</sub> .....			69	
Yt.....			35	35	Yt <sub>2</sub> O <sub>3</sub> .....			61	
Zr.....			32	30					

\* See also Table 2.

TABLE 2.—EMISSIVITY AND HEMISPHERICAL RADIATION: AG, AL, AU, CU, MO, PT, AND W

$e_\lambda$ ,  $e_c$ ,  $e_v$  and  $e_t$  = monochromatic, color, visible, and total emissivity, respectively.  $\lambda$  = wave-length;  $s$ ,  $l$  = solid, liquid; M. P. = melting point;  $J_\lambda$  = monochromatic intensity of hemispherical radiation;  $J$  = hemispherical intensity of total radiation;  $t$ ,  $T$  = temperature, °C, °K(absolute). Unit of  $e_\lambda$ ,  $e_c$ ,  $e_v$ ,  $e_t$  = 0.01 = 1%; of  $J$  = 1 watt cm<sup>-2</sup>; of  $\lambda$  = 1 mμ =  $10^{-7}$  cm.

Ag, liquid* (16)			Au (17)			Cu, Solid (18)			Liquid*	
t =	1060°	1117°	t =	949° 1061°	1067° 1177°	t =	991°	1035°	1090°	1174°
λ	e <sub>λ</sub>	e <sub>λ</sub>	λ	e <sub>λ</sub> <sup>s</sup>	e <sub>λ</sub> <sup>l</sup>	λ	e <sub>λ</sub>	e <sub>λ</sub>	e <sub>λ</sub>	e <sub>λ</sub>
			475.0		50.3					
500	8.17	9.48	496.1	53.1	47.3	500	38.9	42.1	37.4	40.2
525	8.49	9.03	518.6	49.5	43.4	525	35.5	36.7	33.0	34.9
550	8.06	8.27	541.8	37.1	39.0	550	30.8	31.9	29.8	28.6
575	7.75	7.74	564.9	30.1	34.7	575	23.7	25.7	25.1	24.4
600	7.17	7.58	589.5	22.9	30.4	600	17.3	20.1	21.0	19.7
625	6.97	7.37	614.9	17.4	26.3	625	13.0	15.0	17.1	16.7
650	7.22	7.30	640.9	14.4	23.2	650	10.4	12.4	14.8	14.6
675	6.90	7.41	671.2	11.5	20.3	675	9.5	11.1	12.3	13.0
700	6.66	7.21	701.4	10.3	18.4	700	7.7	9.4	10.6	12.4
(1) M. P.	M. P.	M. P.	(1) M. P.	M. P.	M. P.	(1) M. P.	M. P.	M. P.	M. P.	M. P.
550	<35	<35	550	<38	<38	550	38		36	
650	4	7	650	14	22	650	10		15	



Al, liquid	$t$	700	800	850	900	950	1000	(12.1)
$\lambda = 650$	$e_\lambda$	12	12	13	14	15	17	

**Mo (18), assumes  $C_2 = 14\,330$  micron deg.; M. P. of Au =  $1336^\circ\text{K}$**

$\lambda = 475$	665	Visible	Color	Total	$J$	$T \frac{dJ}{J' dT}$
$T$	$e_\lambda$	$e_\lambda$	$e_v$	$e_c$	$e_t$	
273	42.5	42.0				
300	42.4	41.9				
400	42.1	41.5				
600	41.5	40.6				
800	40.9	39.8				
1000	40.3	39.0	39.3	36.1	9.6	0.55
1200	39.8	38.2	38.6	34.7	12.1	1.43
1400	39.3	37.5	37.9	33.3	14.5	3.18
1600	38.8	36.7	37.3	32.1	16.8	6.30
1800	38.3	36.0	36.7	30.9	18.9	11.3
2000	37.9	35.3	36.2	29.7	21.0	19.2
2200	37.5	34.7	35.7	28.7	23.0	30.7
2400	37.1	34.1	35.2	27.7	24.8	47.0
2600	36.8	33.6	34.8	26.8	26.5	69.5
2800	36.5	33.1	34.4	26.0	28.1	98
2895	36.3	32.8	34.2	25.5	29.0	116

Mo, at M. P. and  $\lambda = 650$ ; solid,  $e_\lambda = 43$ ; liquid  $e_\lambda = 40$  (1)

Pt, intensity ( $J_\lambda$ ) of monochromatic radiance; unit of  $J_\lambda =$  (arbitrary) (3)

$\lambda$	$t = 1056^\circ$	1174°	1216°	1271°	1353°	1442°
589						43.30
646						118.4
698			31.51	36.42	34.92	187.9
757		16.49	55.73	55.02	65.60	293.6
836	11.52	31.19	101.3	105.0	107.8	501.1
934	26.79	56.85	200.1	212.6	201.6	772.1
1054	52.46	101.7	319.5	339.9	314.0	1141
1197	85.60	167.2	459.1	494.1	425.0	1395
1357	126.7	234.8	603.1	615.6	514.2	1544
1526	166.4	275.2	680.4	692.1	569.8	1560
1698	176.9	289.2	676.1	682.0	567.6	1409
1868	188.5	287.0	646.0	658.3	528.1	1302
2033	187.8	276.9	617.7	614.1	492.3	1135
2190	176.2	253.9	548.3	559.9	441.5	1014
2410	158.5	225.4	462.0	469.1	380.2	835.8
2546	141.1	197.4	399.7	408.1	350.0	712.2
2801	115.1	152.5	321.7	313.0	251.2	538.8
2921	103.4	139.4	284.2	279.3	224.2	464.3
3037	94.76	123.1	252.0	255.4	206.9	426.6
3150	84.61	115.9	232.1	235.9	191.0	384.5
3367	77.10	99.78	211.6	202.3	158.3	328.1
3569	70.93	89.82	178.0	174.7	137.7	283.5
3760	64.54	75.19	149.6	155.6	120.0	252.2
4031	50.80	67.03	121.2	125.7	103.6	198.5
4446	40.09	47.78	96.99	96.80	74.86	147.2
4638	35.78	42.84	84.12	85.05	65.90	129.3
4827	29.50	38.06	74.64	72.13	55.93	111.4
5001	28.30	34.00	62.53	64.46	50.40	101.1
5168	25.20	30.63	56.00	57.26	46.92	88.60
5486		26.52	40.39	48.46	36.32	75.35
6240			27.61	30.59	25.12	41.72

Pt, ( $J_\lambda$ ) (3).—(Continued)				Pt, total emissivity† (7)		
$\lambda$	$t = 1481^\circ$	1625°	1691°	$T$	$e_{\text{calc.}}$	$e_{\text{obs.}}$
589	37.38	126.0	162.4	300	4.11	3.59
646	94.80	257.1	295.0	350	4.77	4.10
698	154.6	348.9	461.9	400	5.43	4.66
757	237.3	549.5	724.7	450	6.06	5.30
836	382.4	830.3	1064	500	6.68	5.98
934	581.9	1176	1436	550	7.29	6.71
1054	859.2	1639	1815	600	7.90	7.50
1197	1073	1840	2096	650	8.48	8.25
1357	1217	1929	2225	700	9.07	9.05
1526	1225	1901	2140	750	9.61	9.79
1698	1143	1728	1885	800	10.14	10.52
1868	1047	1528	1675	850	10.7	11.3
2033	932.4	1238	1442	900	11.2	12.0
2190	830.3	1156	1279	950	11.7	12.7
2410	699.8	869.0	1015	1000	12.2	13.4
2546	624.0	811.4	841.7	1050	12.7	14.1
2801	444.8	599.5	640.5	1100	13.2	14.7
2921	394.0	530.5	563.0	1150	13.7	15.3
3037	364.0	460.0	497.3	1200	14.1	15.9
3150	318.8	432.5	445.6	1250	14.6	16.5
3367	270.8	358.0	362.8	1300	15.0	17.1
3569	238.5	292.9	315.0	1350	15.5	17.6
3760	206.0	265.0	273.2	1400	15.9	18.2
4031	168.8	225.1	217.2	1450	16.3	18.7
4446	123.8	152.0	158.7	1500	16.7	19.2
4638	105.0	140.0	140.8			
4827	92.60	125.3	114.2	Pt, monochromatic emissivity		
5001	80.22	105.0	107.4	$\lambda$ .....	536	647
5168	75.79	90.61	98.79	$e_\lambda$ † (10).....	36.3	34.8
5486	61.34	69.20	78.81	$\lambda$ .....	550	650
6240	35.81	38.66	44.92	$e_\lambda$ (1).....	38	33 s
6852	22.50	25.64	29.28	$t = \text{M. P.}$		38 l

For platinum black, see Table 4.

W (18), data apply to aged tungsten filaments

$\lambda =$	467	665	Visible	Color	Total	Crova	$J$	$T \frac{dJ}{J' dT}$
$T$	$e_\lambda$	$e_\lambda$	$e_v$	$e_c$	$e_t$	$\lambda_c$		
300	50.5	47.0			3.2		0.0015	
400	50.1	46.8			4.2		0.006	
500	49.8	46.6			5.3		0.019	
600	49.5	46.4			6.4		0.048	
700	49.2	46.2			7.6		0.105	
800	49.0	46.0			8.8		0.206	
900	48.8	45.8			10.1		0.379	
1000	48.6	45.6	46.4	39.6	11.4	607.7	0.654	5.35
1100	48.4	45.4	46.3	39.3	12.8	603.8	1.072	5.35
1200	48.2	45.2	46.2	39.1	14.4	600.4	1.691	5.35
1300	48.0	45.0	46.0	38.8	15.8	597.1	2.576	5.35
1400	47.8	44.8	45.9	38.6	17.4	593.4	3.82	5.29
1500	47.6	44.5	45.7	38.3	19.2	590.2	5.55	5.23
1600	47.5	44.3	45.6	38.1	20.7	587.4	7.77	5.15
1700	47.3	44.1	45.5	37.8	22.2	585.0	10.59	5.07
1800	47.2	43.9	45.4	37.6	23.6	582.6	14.22	4.99
1900	47.0	43.7	45.3	37.3	24.9	580.6	18.25	4.91
2000	46.9	43.5	45.2	37.0	26.0	578.5	23.72	4.85
2100	46.7	43.3	45.0	36.7	27.0	576.9	29.86	4.79
2200	46.6	43.1	44.9	36.4	27.9	575.3	37.18	4.74
2300	46.4	42.9	44.8	36.2	28.8	573.7	45.9	4.69
2400	46.3	42.7	44.7	35.9	29.6	572.4	55.8	4.64



W (18).—(Continued)

$\lambda =$	467	665	Visible	Color	Total	Crova	$J$	$T \frac{dJ}{J' dT}$
$T$	$e_\lambda$	$e_\lambda$	$e_v$	$e_c$	$e_t$	$\lambda_c$		
2500	46.2	42.5	44.6	35.6	30.2	571.1	67.6	4.59
2600	46.0	42.3	44.4	35.3	31.1	570.1	80.8	4.55
2700	45.9	42.1	44.3	35.0	31.8	569.1	96.2	4.51
2800	45.8	41.9	44.2	34.7	32.3	568.2	112.9	4.47
2900	45.6	41.7	44.1	34.5	32.9	567.4	132.1	4.43
3000	45.5	41.5	44.0	34.3	33.4	566.6	153.9	4.40
3100	45.4	41.3	43.8	34.1	33.7	565.9	177.5	4.37
3200	45.2	41.1	43.7	33.8§	34.1§	565.2	203	4.34
3300	45.1	40.9	43.6	33.5§	34.4§	564.5	232	4.31
3400	45.0§	40.7§	43.5§	33.2§	34.8§	563.8	264§	4.29
3500	44.9§	40.5§	43.4§	32.9§	35.1§	563.1	300§	4.27
3655	44.7§	40.2§	43.3§	32.4§	35.4§	562.1	360§	

W,  $t = 2000$  to  $3200^\circ\text{C}$ ,  $e_\lambda = 49$ , same for  $\lambda = 536$  as for  $\lambda = 647$ ; independent of  $t$  (10); others (8, 12) have found  $e_\lambda$  varies with  $t$ . For solid W at M. P.,  $\lambda = 650$ ,  $e_\lambda = 39$  (1).

\* Fused in H.  
† Radiator was a Pt wire in a highly evacuated enclosure;  $e_{\text{calc.}} = 0.751 \times \sqrt{T_p - 0.632T_p + 0.670(T_p)^{3/2} - 0.607(T_p)^2}$ , where  $\rho$  = resistivity (ohm-cm), and  $T$  = absolute temperature ( $^\circ\text{K}$ );  $e_{\text{obs.}}$  = observed emissivity.  
‡ Between  $20^\circ\text{C}$  and  $1710^\circ\text{C}$ ,  $e_\lambda$  is independent of  $t$ .  
§ Extrapolated values.

TABLE 3.—TOTAL EMISSIVITY ( $e_t$ ) OF OXIDIZED METALS (15)  
Surfaces were oxidized at  $t \leq 600^\circ\text{C}$ ; Unit of  $e_t = 0.01 = 1\%$

Metal	200°C	400°C	600°C
Ag, Silver.....	2.0	3.0	3.8
Al, Aluminum*.....	11.3	15.3	19.2
Cu, Copper†.....	18.0	18.5	19.0
Cu, Copper*.....	56.8	56.8	56.8
Cu-Zn, Brass*.....	61.0	60.0	58.9
Fe, Cast iron.....	21.0		
Fe, Cast iron*.....	64.3	71.0	77.7
Steel†.....	52.1	54.7	57.0
Steel*.....	79.0	78.8	78.7
Ni, Nickel*.....	36.9	42.4	47.8
Ni-Cu, Monel*.....	41.1	43.9	46.3
Pb, Lead*.....	63.1		
Pt, Platinum.....	6.0	8.6	11.0
Zn, Zinc*.....		11.0	

\* Oxidized. † Calorized surface.  
TABLE 4.—TOTAL EMISSIVITY ( $e_t$ ) OF PLATINUM BLACK AND OF LAMPBLACK: VARIATION WITH THICKNESS (11)  
Deposited upon Pt. The lampblack was covered with lacquer.  $D_s$  = surface density of the black. Unit of  $D_s = 10^{-6} \text{ g cm}^{-2} = 0.001 \text{ mg cm}^{-2}$ ; of  $e_t = 0.01 = 1\%$ . Temperature =  $100^\circ\text{C}$ .

Pt Black		Lampblack	
$D_s$	$e_t$	$D_s$	$e_t$
37	7.8	22	33.0
150	12.9	25	40.7
224	23.4	79	58.0
257	31.1	79	64.0
286	46.5	90	72.9
327	58.5	97	77.6
412	72.9	126	82.5
599	89.3	173	89.8
827	93.5	242	93.1
942	94.2	267	94.9
1072	94.9	300	94.2
1140	95.3	332	94.5
1897	96.8	339	94.0
3185	96.7	527	93.1
		1182	88.2

TABLE 5.—EFFICIENCY OF COATED SHEETS AS SUN-SHIELDS, AND RELATIVE EMISSIVITIES OF PAINTS AND COATINGS (6)

While one side (upper) of a sheet was continuously exposed normally to the sun, the radiation ( $r$ ) proceeding normally from the other side (lower) was measured. If  $r_1$  and  $r_2$  are simultaneous values for two sheets similarly exposed,  $r_2/r_1$  measures the relative efficiency of the second with reference to the first; if the sheets are unperforated and are good thermal conductors,  $r_2/r_1$  is the ratio of the emissivities of the two lower surfaces. All sheets were approximately at  $50^\circ\text{C}$ . Unit of  $r_2/r_1 = 0.01 = 1\%$ .

	Sheet 1		Sheet 2		$r/r_1$
	Upper	Lower	Upper	Lower	
Sheet iron*.....	Asbestos	Asbestos	Asbestos	Al paint	55
Iron, 6 mm†.....	Black‡	Oxidised	Al paint	Al paint	73
			Al paint	Oxidised	50
Iron, 0.5 mm†.....	Black	Al paint d.§ White lead	White lead	Oxidised	30
			Black	Al paint p.§	100
			Black	Lampblack	95, 100
			Black	Al paint	28, 29
			Black	Enamel	98, 100
			Black	Enamel	96, 98
Cypress, 12.7 mm†.....	Black	Lampblack	Black	Al paint	27, 30
Rubberised cloth¶.....	Unpainted	Unpainted	Unpainted	Al paint	43
Leatheroid** (1).....	Rubber	Cloth	Al paint	Cloth	45
(2).....	Unpainted	Unpainted	Unpainted	Al paint	44
			Al paint	Unpainted	30
			Al paint	Unpainted	25
(3).....	Unpainted	Unpainted	Unpainted	Al paint	37
			Al paint	Unpainted	27
			Al paint	Unpainted	14, 15
Duck, 11 H††.....	Unpainted	Unpainted	Unpainted	Al paint	22, 23
Duck, 4 H††.....	Unpainted	Unpainted	Unpainted	Al paint	22, 25
Duck†† (12 H; 4 H)††.....	Unpainted	Al paint	Unpainted	Al paint	80, 81
Duck†† (12 H; 4 H)††.....	Unpainted	Unpainted	Unpainted	Unpainted	58

\* Corrugated asbestos roofing. Temperature in shade =  $29^\circ\text{C}$ ; temperature of sheet with asbestos on both sides =  $44^\circ\text{C}$ ; asbestos upper, Al lower =  $45^\circ\text{C}$ ; Al both sides =  $52^\circ\text{C}$ ; Zn sprayed on both sides =  $55^\circ\text{C}$ .  
† Thickness of sheet. ‡ Asphalt paint. § d., p. = dull, polished. || White, vitreous enamel.  
¶ Balloon fabric.  
\*\* Artificial leather: (1) Single fabric. (2) Double fabric enclosing thin layer of rubber-friction stock. (3) Similar to (2), but of double-texture fabric. All three were coated on upper side with a black, rubber composition.  
†† Cotton duck; 11 H is 13.08 oz./yd.<sup>2</sup>; 4 H is 24.54 oz./yd.<sup>2</sup>; 12 H is 11.45 oz./yd.<sup>2</sup>  
‡‡ Sheet 1 is 12 H; sheet 2 is 4 H.

TABLE 6.—LOSS OF HEAT FROM VERTICAL BRICK WALL (2)

In still air at  $21^\circ\text{C}$ , the wall, at the surface temperature  $t$ , lost heat, from one side, at the rate  $E$ .  $E$  is the same for the natural color (red), for brick coated with  $\text{Ca}(\text{OH})_2$ , and for brick coated with lampblack. Uncertainty in  $t$  is about 2%. Unit of  $E = 0.001 \text{ watt/cm}^2 = 2.39 \times 10^{-4} \text{ cal cm}^{-2} \text{ sec}^{-1} = 6.12 \times 10^{-6} \text{ BTU in.}^{-2} \text{ sec}^{-1}$ .

$t$ .....	47°C	66°C	86°C	131°C	199°C	218°C
$E$ .....	30.8	61.7	92.5	185	370	431

TABLE 7.—NORMAL IRRADIATION ( $R$ ) BY HEFNER STANDARD LAMP AND BY SPERM CANDLE: DISTANCE = 1 METER

$R$  = radiant power, per unit area of receiving surface, which is received by a surface which is normal to the direction of propagation of the radiation and 1 meter from the source. Unit of  $R = 10^{-6} \text{ watt/cm}^2 = 2.389 \times 10^{-6} \text{ cal cm}^{-2} \text{ sec}^{-1} = 6.118 \times 10^{-6} \text{ BTU in.}^{-2} \text{ sec}^{-1}$ .

Source	$R$	Remarks	Lit.
1 Sperm candle.....	12.1		(4)
1 Hefner lamp.....	10.9*		(4)
	9.6†		(4)
	9.47†	Amyl acetate, ordinary	(9)
	9.40†	Amyl acetate, pure	(9)
	9.43†	Isoamyl acetate	(9)

\* No diaphragm. † Diaphragm, opening 14 mm by 50 mm.



**TABLE 8.—MONOCHROMATIC EMISSIVITY ( $\epsilon_\lambda$ ) AND MONOCHROMATIC INTENSITY ( $J_\lambda$ ) OF RADIATION OF WELSBACH GAS MANTLE (14)**

The mantle contained 0.993 ThO<sub>2</sub> per 0.007 Ce<sub>2</sub>O<sub>3</sub>;  $J_\lambda$  depends upon relative amount of Ce<sub>2</sub>O<sub>3</sub>.  $\epsilon_\lambda$  is computed on assumption that true absolute temperature of mantle = 1800°K. Unit of  $\lambda$  =  $1\mu$  = 0.001 mm =  $10^4\text{\AA}$ ; of  $J_\lambda$  = (arbitrary); of  $\epsilon_\lambda$  = 0.01 = 1%.

$\lambda$	$J_\lambda$	$\epsilon_\lambda$	$\lambda$	$J_\lambda$	$\epsilon_\lambda$	$\lambda$	$J_\lambda$	$\epsilon_\lambda$
0.45	3.8	86	1.5	34.0	0.9	8.0	23.9	21
0.50	11.5	72	2.0	25.5	0.7	9.0	29.9	39
0.55	22.0	49	3.0	17.0	0.9	10.0	27.4	52
0.60	24.0	24	4.0	7.6	0.8	12.0	19.1	70
0.70	25.8	6.2	5.0	7.0	1.4	15.0	8.9	79
1.0	34.3	1.9	6.0	7.9	2.7	18.0	5.0	81
1.2	34.3	1.2	7.0	15.0	8.4			

**TABLE 9.—MONOCHROMATIC INTENSITY ( $J_\lambda$ ) OF RADIATION FROM A CYLINDRICAL ACETYLENE FLAME (5)**

The value of  $J_\lambda$  for a flat flame, whether viewed flatwise or edgewise, is different from that for a cylindrical flame.  $J'_\lambda$  is the intensity of the radiation from a black-body at 2360°K, assuming  $C_2$  = 14350 micron °K. Unit of  $\lambda$  =  $10^{-3}\mu$  =  $10^{-7}$  cm =  $10\text{\AA}$ ; of  $J_\lambda$  = of  $J'_\lambda$  = (arbitrary); of  $J_\lambda/J'_\lambda$  = 0.01 = 1%.

$\lambda$	$J_\lambda$	$J'_\lambda$	$J_\lambda/J'_\lambda$	$\lambda$	$J_\lambda$	$J'_\lambda$	$J_\lambda/J'_\lambda$
400	5	3.3	66	460	11.8	11.2	94.9
425	7	5.5	79	475	15.0	14.6	97.4
440	8.5	7.6	89.4	500	20.9	21.0	100.5
450	10.0	9.25	92.5	520	27.5	27.3	99.3

$\lambda$	$J_\lambda$	$J'_\lambda$	$J_\lambda/J'_\lambda$	$\lambda$	$J_\lambda$	$J'_\lambda$	$J_\lambda/J'_\lambda$
525	29.2	29.2	100.0	650	91.2	92.1	101.0
540	34.6	34.6	100.0	660	97.6	98.5	100.7
550	38.9	38.8	99.8	675	107.5	108.0	100.4
560	42.9	43.1	100.4	680	110.9	111.3	100.7
575	49.8	49.9	100.2	700	124.1	124.1	100.0
580	52.2	52.4	100.3	720	137.5	137.2	99.8
600	62.5	62.9	100.6	725	141.0	140.5	99.6
620	73.3	74.0	101.1	740	151.0	150.2	99.5
625	76.1	76.8	100.8	750	157.9	157.2	99.5
640	85.0	86.0	101.1	750	163.0	157.2	96.5

**TABLE 10.—MONOCHROMATIC INTENSITY ( $J_\lambda$ ) OF RADIATION OF A GAS-FILLED TUNGSTEN LAMP (13)**

Color temperature = 2848°K; efficiency = 15.6 lumen per watt. Unit of  $\lambda$  =  $10^{-2}\mu$  =  $10^{-6}$  cm =  $100\text{\AA}$ ; of  $J_\lambda$  = (arbitrary).

$\lambda$	40	42	44	46	48	50	52	54	56
$J_\lambda$	35	45	57.5	73.5	94.0	116.5	141	167.5	196
$\lambda$	58	60	62	64	66	68	70	72	74
$J_\lambda$	224	252	280	307.5	336.5	365	393	421	450

## LITERATURE

(For a key to the periodicals see end of volume)

- (1) Burgess and Waltenberg, *31A*, 11: 591; 15. (2) Celite Products Co., Chicago, Ill., 0. (3) Coblenz, *31A*, 9: 81; 12. (4) Coblenz, *31A*, 11: 87; 15. (5) Coblenz, *31A*, 15: 639; 20. (6) Coblenz and Hughes, *32*, No. 254; 24. (7) Davison and Weeks, *48*, 8: 581; 24. (8) Foote, *128*, 6: 317; 16. (9) Gerlach, *63*, 14: 577; 13. (10) Henning and Heuse, *96*, 16: 63; 23. (11) Kurlbaum, *8*, 67: 846; 99. (12) Langmuir, *2*, 7: 302; 16. (12-1) Moeller and Miething, *Giesserei-Ztg.*, 21: 444; 24. (13) Priest, *48*, 6: 27; 22. (14) Rubens, *8*, 18: 725; 05. 20: 593; 06. (15) Randolph and Overholser, *2*, 2: 144; 13. (16) Stubbs, *5*, 88: 195; 13. (17) Stubbs and Prideaux, *5*, 87: 451; 12. (18) Worthing, A. S., National Electric Lamp Assn., Nela Park, Cleveland, O., 0.

## TEMPERATURE, BRIGHTNESS AND EFFICIENCY OF SELECTED SOURCES OF LIGHT

W. E. FORSYTHE

(All data and computations not credited to another have been supplied by the Nela Research Laboratory, Cleveland, Ohio, U. S. A.)

## Definitions

The *brightness temperature* of a body ( $B$ ) for a stated wavelength (frequently,  $\lambda$  =  $0.665\mu$ ) is the temperature at which an ideal black-body has, at this wave-length, the same brightness as  $B$ .

The *color temperature* of a body ( $B$ ) is the temperature at which an ideal black-body has the same integral (or apparent) color as  $B$ .

The *radiation temperature* of a body ( $B$ ) is the temperature at which the rate of total energy radiation from an ideal black-body is equal to that from  $B$ .

By the *brightness* of a source is meant the brightness in the direction perpendicular to the emitting surface.

**TABLE 1.—BRIGHTNESS TEMPERATURE ( $\lambda$  =  $0.665\mu$ ) CORRESPONDING TO TRUE TEMPERATURE  $T$**   
 $T$  = true absolute temperature, °K

$T$	C* (8)	Mo (14)	Ni (14)	Pt (14)	Ta (14)	W (12)	Nernst glower (11)
1000	995	958	956	950	966	966	
1100	1092	1049	1047	1037	1058	1058	959
1200	1189	1139	1137	1124	1149	1149	1065
1300	1286	1228	1226	1211	1239	1240	1271
1400	1382	1316	1315	1296	1329	1330	1277
1500	1478	1403	1403	1381	1418	1420	1384
1600	1574	1489		1466	1506	1509	1491

$T$	C* (8)	Mo (14)	Ni (14)	Pt (14)	Ta (14)	W (12)	Nernst glower (11)
1700	1670	1574		1551	1592	1597	1598
1800	1766	1658		1634	1680	1684	1705
1900	1862	1741		1717	1766	1771	1814
2000	1958	1824		1800	1851	1857	1922
2100	2054	1905			1935	1943	2030
2200	2150	1986			2018	2026	2140
2300	2245	2065			2099	2109	2250
2400	2340	2143			2180	2192	2361
2500		2220			2260	2274	2472
2600		2297			2339	2356	
2700		2373			2417	2437	
2800		2448			2495	2516	
2900		2523			2571	2595	
3000					2647	2673	

$T$	Au (14)	Cu† (3)	Fe† (3)	FeO† (3)	Ni <sub>2</sub> O <sub>3</sub> † (3)	Ni-Cr‡ (3)	Slag† (3)
1000	908			1000	999	997	
1100	990			1099	1098	1095	
1200	1071			1197	1196	1193	
1300	1151			1295	1292	1289	
1400		1255		1392	1389	1383	
1500		1335	1412	1489	1484	1475	



TABLE 1.—(Continued)

$T$	Au (14)	Cu† (3)	Fe† (3)	FeO† (3)	Ni <sub>2</sub> O <sub>3</sub> † (3)	Ni-Cr§ (3)	Slag† (3)
1600		1413	1499		1580		
1700		1490	1586				1646
1800		1566	1673				1738
1900			1759				1831
2000			1844				1924
2100			1929				
2200			2016				

\* Untreated carbon filament.

† Molten.

‡ Solid.

§ Nichrome, chromel.

TABLE 2.—COLOR TEMPERATURE CORRESPONDING TO TRUE TEMPERATURE ( $T$ ) (°) AND TABLE 1 $T$  = true absolute temperature, °K

$T$	C*	Mo	Ni	Pt	Ta	W	Nernst glower
1000		1004	1020	1011		1006	
1100		1105	1125	1116		1108	
1200		1207	1231	1222		1210	
1300	1300	1309	1336	1328		1312	
1400	1396	1411	1442	1435		1414	
1500	1492	1513	1546	1542	1532	1517	1517
1600	1590	1616		1649	1642	1619	1631
1700	1687	1720		1757	1751	1722	1744
1800	1785	1823		1865	1859	1825	1857
1900	1884	1927		1974	1967	1929	1968
2000	1984	2032		2083	2075	2033	2074
2100	2086	2138			2182	2137	2173
2200	2187	2244			2288	2242	2265
2300	2288	2350			2393	2347	2345
2400		2456			2497	2452	2426
2500		2563			2601	2557	2502
2600		2672			2705	2663	
2800		2891			2911	2878	
3000						3094	

\* Untreated carbon filament.

TABLE 3.—COLOR TEMPERATURE CORRESPONDING TO BRIGHTNESS TEMPERATURE ( $T_B$ ) (°) AND TABLE 1 $T_B$  = brightness temperature, absolute, °K

$T_B$	C*	C†	Os
1400	1414		1444
1500	1515		1562
1600	1616	1620	1680
1700	1718	1735	1799
1800	1820	1852	1919
1900	1923	1962	2045
2000	2028	2064	2168
2100	2134	2161	2295
2200	2240	2255	2427
2300			2556
2400			2688

\* Untreated carbon filament.

† Treated carbon filament, "Gem."

TABLE 4.—RADIATION TEMPERATURE CORRESPONDING TO TRUE TEMPERATURE ( $T$ ) $T$  = true absolute temperature, °K

$T$	Cu* (3)	CuO (3)	Fe* (3)	FeO (3)	Mo (14)	Ni <sub>2</sub> O <sub>3</sub> (3)	Pt (13)	W (5)
1000		880		963	557	892	562	581
1100		961		1060	633	1003	632	659
1200		1156		1156	708	1112	704	738
1300	815	1245		1251	786	1220	775	819
1400	873	1334		1346	864	1332	849	905
1500	934	1424	1092	1442	945	1442	922	991
1600	1000	1514	1163		1024		995	1080
1700			1235		1106		1070	1167
1800			1307		1187		1146	1254
1900			1382		1272		1222	1342
2000			1456		1354		1297	1428
2200					1523			1601
2400					1693			1775
2600					1866			1945
2800					2039			2116
3000								2286

\* Molten.

TABLE 5.—BRIGHTNESS\* ( $B$ ) CORRESPONDING TO TRUE TEMPERATURE

$T$  = true absolute temperature, °K;  $B = A \times 10^4$ . Examples: W has a brightness of 0.00012 candle/cm<sup>2</sup> at 1000°K, of 2.26 at 1700°K, and of 347 candle/cm<sup>2</sup> at 2600°K. Unit of  $B = 1$  candle/cm<sup>2</sup> = 6.452 candle/in.<sup>2</sup> = 3.142 lambert.

$T$	$n$	B. B.†	W	Mo	Ta	C†	Nernst§	Pt	Ni	$n$
$A$										
1000	-4	2.5	1.2	1.0		2.0		0.7	0.9	-4
1100	-4	21	10	8.1		17.4		6.2	8.0	-4
1200	-2	1.30	0.6	0.50		1.1		0.43	0.52	-2
1300	-2	6.4	2.9	2.4		5.4		2.04	2.5	-2
1400	-1	2.35	1.1	0.89		1.9	0.5	0.74	0.90	-1
1500	-1	7.22	3.3	2.7	3.2	6.0	2.2	2.4	2.8	-1
1600	-1	20.5	9.2	7.65	9.1	16.2	7.8	6.43		-1
1700	0	5.06	2.26	1.87	2.21	4.05	2.27	1.61		0
1800	0	11.25	5.05	4.13	5.04	8.89	6.0	3.56		0
1900	0	22.9	10.40	8.34	10.35	18.5	14.0	7.5		0
2000	1	4.39	2.00	1.59	2.02	3.44	2.93	1.43		1
2100	1	7.94	3.56	2.86	3.63	6.30	5.70			1
2200	1	13.62	6.13	4.85	6.23	10.69	10.6			1
2300	1	22.47	10.05	7.95	9.45	24.45	20.6			1
2400	2	3.50	1.570	1.23	1.46		3.72			2
2500	2	5.31	2.375	1.86	2.22					
2600	2	7.75	3.470	2.70	3.24					
2700	2	11.30	4.980	3.91	4.57					
2800	2	15.80	6.94	5.40	6.16					
2900	2	21.60	9.49							
3000	2	28.90	12.57							
3100	2	37.60	16.47							
3200	2	48.50	21.10							
3300	2	61.10	26.85							
3400	3	7.42	3.37							
3500	3	8.82	4.22							
3600	3	10.30	5.74							

\* Computed from brightness of black-body (°) and data in Table 2.

† Black-body (°); data for  $T = 1000$  to  $1600^\circ$  and  $2700$  to  $3600^\circ$  are calculated.

‡ Untreated carbon filament.

§ Nernst glower.



TABLE 6.—BRIGHTNESS\* (B) CORRESPONDING TO COLOR TEMPERATURE (T<sub>c</sub>)

T<sub>c</sub> = absolute color temperature, °K. Unit of B = 1 candle/cm<sup>2</sup> = 6.452 candle/in.<sup>2</sup> = 3.142 lambert.

T <sub>c</sub>	B		
	C†	C‡	Os
1400	0.20		0.15
1500	0.62		0.43
1600	1.8	1.8	1.15
1700	4.4	4.1	2.60
1800	9.9	8.9	5.7
1900	20.0	17.4	11.0
2000	39.0	32.5	20.5
2100	68	57.5	35.0
2200	117	102	59.0
2300	187	171	93.0
2400			144.0
2500			209
2600			306
2700			427
2800			590

\* Computed from brightness of black-body (\*) and data of Table 2.

† Untreated carbon filament.

‡ Treated carbon filament, "Gem."

TABLE 7.—TEMPERATURE, BRIGHTNESS AND EFFICIENCY OF SELECTED SOURCES OF ILLUMINATION

T, T<sub>B</sub>, T<sub>c</sub> = true, brightness, and color temperature, absolute scale, expressed in °K; E = efficiency; B = intrinsic brightness; C = carbon, Os = Osmium, Ta = Tantalum, W = Tungsten; 50-w. = 50 watt; w.p.c. = watt per candle; cp. std. = candle power standard. Unit of B = 1 candle/cm<sup>2</sup> = 6.452 candle/in.<sup>2</sup> = 3.142 lambert; of E = 1 lumen/watt.

Source	T	T <sub>B</sub>	T <sub>c</sub>	E	B	Remarks
Candle: sperm.....			1 930		1.0	Bright spot
Paraffin.....			1 925			
Kerosene: flat.....	1 500	2 065			1.2	Bright spot
Round.....	1 530	1 920			1.5	Bright spot
Hefner lamp.....		1 880			0.7	Bright spot
Pentane lamp*.....		1 920				10 cp. std.
Gas: flame†.....		2 160				Batawing
		1 875				Candle
Mantle.....					6.2	Bright spot
Acetylene‡.....		2 380				Whole flame
	1 660	2 465			6.7	One spot
	1 730	2 360			10.8	Mees burner
Vacuum lamps:						
C, 4 w.p.c.....	2 030	2 080	2.5	55		Filament
3.1 w.p.c.....	2 065	2 165	3.2	71		Treated
2.5 w.p.c.....	2 130	2 195	4.0	78		Gem
50-w.....	2 095	2 080	2.5	55		Untreated (*)
50-w.....	2 130	2 195	4.0	78		Gem (*)
Vacuum lamps:						
Os, 2 w.p.c.....	2 035	2 185	6.3	61		
Ta, 2 w.p.c.....	2 000	2 260	6.3	53		
50-w.....	2 180	2 260	6.3	53		(*)
W, 10-w.....	2 355	2 390	7.7	128		Straight‡‡ (*)
25-w.....	2 450	2 493	9.8	193		Straight‡‡ (*)
40-w.....	2 460	2 504	10.0	206‡		Straight‡‡ (*)
60-w.....	2 465	2 509	10.1	211		Straight‡‡ (*)

Source	T	T <sub>B</sub>	T <sub>c</sub>	E	B	Remarks
W, Bulb frosted on inside (*):						
15-w.....	2 470			8.4	2.3	Coiled
25-w.....	2 505			9.5	4.1	Coiled
40-w.....	2 535			10.0	5.2	Coiled
Gas-filled lamps (*):						
W, 50-w.....					408	White masda
50-w.....	2 685	2 670	10.0		469	
75-w.....	2 735	2 705	11.8		563	White masda‡
100-w.....	2 760	2 740	12.9		605	
200-w.....	2 840	2 810	15.2		781	
200-w.....	2 860		10.0			"Daylight"
500-w.....	2 960		11.2			"Daylight"
750-w.....	3 065					Photographic
900-w.....	3 290	3 220	27.3	2 660		Special**
1000-w.....	2 990	2 980	20.0	1 225		
1000-w.....	3 185	3 175	24.2	2 065		Stereopticon
1500-w.....	3 105					Photographic
2000-w.....	3 020	3 000	21.2	1 350		Masda††
10 kw.....	3 350	3 300	31.0	3 050		Special**
30 kw.....	3 350	3 300	31.0	3 050		Special**
Bulb frosted on inside (*):						
50-w.....	2 650		10.0	7.8		Coiled
60-w.....	2 655		11.1	9.2		Coiled
100-w.....	2 765		13.4	12.3		Coiled
Electric arc:						
Solid C.....		3 385	3 780		9 200	(1°)
Cored C.....		3 075	3 420		4 130	(1°)
Graphite (C).....		3 735	3 775		17 300	(1°)
Hg, 385-w.....	(2)	Direct current		2.2		110 volt
430-w.....	(2)	Alternating current		2.4		110 volt
500-w.....	(2)	Quartz tube		350		100 volt
Clear sky (7).....					0.8	Average
Moon (4).....					0.25	Bright spot
Sun†† (as observed from surface of earth)					165 000	
(As observed from top of earth's atmosphere)					224 000	

\* Color-matched by Bureau of Standards.

† Mixture of coal gas and water gas, heating value ca. 600 BTU/ft.<sup>3</sup>; "batawing" and "candle" refer to the shape of the flame; the candle-shaped flame was about 10 cm high.

‡ For first two lines, the burner was from a "prest-o-lite" automobile headlight, reflector removed; for third line, a Mees burner was used.

§ For frosted bulb, B = 2.5; for "golden masda" bulb, B = 2.0 (\*).

|| For bulb, B = 1.3.

¶ Filament, sprayed; for bulb, B = 2.1.

\*\* For special illumination.

†† For inside surface of coil, B = 3 000; for frosted bulb, B = 130.

‡‡ Calculated from data of (1).

§§ Straight filament.

## LITERATURE

(For a key to the periodicals see end of volume)

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## OPTICAL CONSTANTS OF SUBSTANCES WHICH EXHIBIT METALLIC REFLECTION

JOSEPH VALASEK

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## INTRODUCTION

When the angle of incidence is not zero, the light reflected from a metal is elliptically polarized unless the incident light is plane polarized either in or perpendicular to the plane of incidence. Since the reflectivity and the ellipticity are very sensitive to changes in the condition of the surface, published values of the optical constants are quite discordant. The values are here classified according to the preparation of the mirror, since this seems to affect the results in many cases. To obtain the dispersion of the optical constants of some materials, it may be necessary to use data from several tables. It should also be observed that the reflectivity may be calculated from the indices of refraction and absorption with the aid of the formula given in the following section. The values in the reflectivity tables may be supplemented in this way, if necessary.

For all substances in which the index of absorption is not zero, both it and the index of refraction vary with the angle of incidence (27.1, 48.1).

Optical constants of dyes and vapors of metals, and data in regard to spectra, emissivity, magneto-optics, photoelectricity, photoconductivity, X-rays, and  $\gamma$ -rays are covered by other reports; see index.

## SYMBOLS AND NUMERICAL RELATIONS

$A$	100 $\times$ absorption by a thin film; $A = 100 - (R + T)$ .
$J_0, J_z$	Intensity of parallel light at two planes within the substance, the planes being perpendicular to the direction of propagation of the light, and separated by the distance $z$ .
$J_i, J_r, J_t$	Intensity of the incident, transmitted and reflected light.
$k$	Index of absorption for normal incidence in the direction of $z$ ; $J_z = J_0 e^{-4\pi k z / \lambda_0}$ , $z$ and $\lambda_0$ are to be expressed in the same units.
$k_\theta$	Index of absorption for incidence at an angle $\theta$ with the normal $z$ ; $J_z = J_0 e^{-4\pi k_\theta z / \lambda_0}$ .

$n$	Index of refraction for normal incidence = ratio of wave or phase velocity of light in <i>vacuo</i> ( $V$ ) to that in the substance ( $v$ ); $n = V/v = \lambda_0/\lambda$ .
$n_\theta$	Index of refraction for angle of incidence $\theta$ ; $n_\theta = \sin \theta / \sin \rho$ .
$R$	100 $\times$ reflectivity; $R = 100J_r/J_i$ .
$R_0$	Value of $R$ when $\theta = 0$ .
$R_{  } [R_{\perp}]$	Value of $R$ when incident light is plane polarized with electric vector parallel [perpendicular] to the plane of incidence.
$T$	100 $\times$ transmissivity of a thin film; $T = 100J_t/J_i$ .
$u_{  } [u_{\perp}]$	Component of amplitude of reflected light with electric vector $\parallel [\perp]$ plane of incidence.
$\Delta$	Difference in phase of $u_{  }$ and $u_{\perp}$ .
$\lambda$	Wave-length in metal of refracted light.
$\lambda_0$	Wave-length in <i>vacuo</i> of incident light.
$\rho$	Angle of refraction; $\rho = \sin^{-1} (n_\theta^{-1} \sin \theta)$ .
$\theta$	Angle of incidence.
$\bar{\theta}$	Principal angle of incidence = value of $\theta$ at which $\Delta = 90^\circ$ .
$\psi$	Azimuth of restored plane of polarization, measured from plane of incidence; $\tan \psi = u_{  }/u_{\perp}$ .
$\bar{\psi}$	Principal azimuth = value of $\psi$ when $\theta = \bar{\theta}$ , i.e., when $\Delta = 90^\circ$ .

For transparent metal films, see (8, 17); for massive metals and opaque films the following relations apply (10, 61):

$$\tan \Delta = \sin Q \tan 2P$$

$$\cos 2\psi = \cos Q \sin 2P$$

where

$$\tan P = \frac{[n^4(1+k^2)^2 - 2n^2(1-k^2)\sin^2\theta + \sin^4\theta]}{\sin\theta \tan\theta}$$

$$= (n\sqrt{1+k^2})/\sin\theta \tan\theta, \text{ approximately:}$$

$$\tan 2Q = \frac{2n^2k}{n^2(1-k^2) - \sin^2\theta}$$

$$\tan Q = k, \text{ approximately.}$$

$$R_0 = 100 \frac{n^2(1+k^2) - 2n + 1}{n^2(1+k^2) + 2n + 1}$$

$$R_{\perp} = 100 \frac{(m_0 - \cos\theta)^2 + m_j k_j}{(m_0 + \cos\theta)^2 + m_j k_j}$$

$$\frac{R_{||}}{R_{\perp}} = \frac{(m_0 - \sin\theta \tan\theta)^2 + m_j k_j}{(m_0 + \sin\theta \tan\theta)^2 + m_j k_j}$$

where

$$m_0 = n_0 \cos \rho$$

$$2m_j = \sqrt{(n^2 - n^2k^2 - \sin^2\theta)^2 + 4n^4k^2} + (n^2 - n^2k^2 - \sin^2\theta)$$

$$2m_j k_j = \sqrt{(n^2 - n^2k^2 - \sin^2\theta)^2 + 4n^4k^2} - (n^2 - n^2k^2 - \sin^2\theta)$$

$$\sin \bar{\theta} \tan \bar{\theta} = n\sqrt{1+k^2} \left[ 1 - \frac{1}{2} \left( \frac{1-k^2}{1+k^2} \right) \frac{\sin^2 \bar{\theta}}{n^2(1+k^2)} + \frac{1}{8} \left( 2 - 3 \left( \frac{1-k^2}{1+k^2} \right)^2 \right) \frac{\sin^4 \bar{\theta}}{n^4(1+k^2)^2} - \dots \right] = n\sqrt{1+k^2},$$

approximately;

$$\tan 2\bar{\psi} = k \left[ 1 + \frac{\sin^2 \bar{\theta}}{n^2(1+k^2)} + \left( \frac{1}{1+k^2} \right) \frac{\sin^4 \bar{\theta}}{n^4(1+k^2)^2} + \dots \right] = k, \text{ approximately.}$$



TABLE 1.—REFRACTION AND ABSORPTION OF PURE MASSIVE METALS, I, MN, MoS<sub>2</sub>, AND STEEL

$J_s = J_{0e^{-\alpha x}}/\lambda_0$ ;  $x$  and  $\lambda_0$  expressed in same unit. Unit of  $\lambda = 1\mu = 10^4\text{\AA} = 10^{-4}\text{ cm.}$

Ag (34)		
$\lambda$	$n$	$k$
0.226	1.41	0.75
.231	1.43	0.78
.250	1.49	0.92
.257	1.53	0.84
.293	1.57	0.62
.298	1.56	0.58
.322	0.83	0.49
.332	.40	1.61
.336	.26	3.21
.346	.22	5.01
.361	.20	7.22
.395	.16	12.3
.450	.16	14.5
.500	.17	17.1
.550	.18	18.8
.589	.18	20.6
.589	.20*	17.1*
.630	.20†	19.5†

\* (29). † (9).

Al (45)		
$\lambda$	$n$	$k$
0.431	0.78	2.85
.486	0.93	3.15
.527	1.10	3.39
.589	1.28	3.66
.589	1.44*	3.64*
.657	1.48	3.92

\* (29).

Au (53); cf. (31, 50, 61)		
$\lambda$	$n$	$k$
0.400	1.58	1.13
.420	1.57	1.15
.440	1.54	1.17
.460	1.45	1.20
.480	1.28	1.32
.500	0.94	1.87
.520	.67	2.99
.540	.54	4.32
.580	.42	6.65
.620	.35	8.95
.660	.32	11.20
.700	.28	13.60

Bi (31); cf. (1)		
$\lambda$	$n$	$k$
0.257	0.99	1.01
.275	0.99	1.15
.298	0.97	1.37
.326	0.98	1.52
.361	1.09	1.64
.398	1.26	1.66
.436	1.80 $l^*$	1.79 $l^*$
.441	1.38	1.64
.468	1.47	1.64
.508	1.55	1.64
.548	2.35 $l^*$	1.63 $l^*$
.579	2.48 $l^*$	1.60 $l^*$
.589	1.78	1.57
.668	1.96	1.58

\* (27);  $l$  = liquid Bi.

C, Graphite (47); cf. (19, 57, 62)		
$\lambda$	$n$	$k$
0.436	1.90	0.36
.492	1.94	.34
.546	1.96	.34
.578	1.97	.33
.623	2.00	.33

Cb (57)		
$\lambda$	$n$	$k$
0.578	1.80	1.17

Cd (9)		
$\lambda$	$n$	$k$
0.436	0.39 $l^*$	9.13 $l^*$
.546	0.76 $l^*$	6.41 $l^*$
.579	0.82 $l^*$	6.27 $l^*$
.589	1.13	4.43
.630	1.31	4.05

\* (27);  $l$  = liquid Cd.

Co (34, 53); cf. (9)		
$\lambda$	$n$	$k$
0.231	1.10*	1.30*
.257	1.25*	1.45*
.275	1.41*	1.52*
.298	1.50*	1.56*
.347	1.54*	1.61*
.395	1.63*	1.79*
.420	1.68	1.83
.440	1.71	1.87
.480	1.86	1.84
.520	1.98	1.83
.560	2.09	1.83
.600	2.21	1.83
.640	2.34	1.82
.680	2.50	1.78

\* (24).

Cr (14); cf. (57)		
$\lambda$	$n$	$k$
0.257	1.64	2.25
.275	1.27	2.45
.298	1.21	2.23
.325	1.26	2.31
.340	1.26	2.35
.347	1.42	2.12
.361	1.53	2.10
.398	1.72	2.13
.415	1.90	2.13
.444	2.36	1.88
.468	2.47	1.88
.480	2.65	1.79
.502	2.93	1.56
.508	3.06	1.53
.533	3.45	1.41
.588	3.59	1.26
.608	3.28	1.31

Ca, Ca-glass mirror (37)		
$\lambda$	$n$	$k$
0.455	0.362	2.37
.489	.339	2.70
.540	.326	3.41
.589	.321	3.70
.641	.326	4.01
.680	.350	4.34

Cu (34, 53); cf. (9, 39, 48, 59)

$\lambda$	$n$	$k$
0.231	1.39*	1.05*
.257	1.40*	1.01*
.275	1.37*	1.01*
.298	1.26*	1.05*
.347	1.19*	1.23*
.395	1.17*	1.50*
.450	1.13*	1.90*
.460	1.19	1.93
.480	1.17	2.00
.500	1.17	2.03
.520	1.15	2.11
.540	1.07	2.25
.560	0.855	2.83
.580	.600	4.66
.589	.62†	4.1†
.589	.64†	4.08†
.600	.565	5.51
.620	.580	5.72
.640	.615	5.82
.660	.655	5.77

\* (34). † (39). ‡ (30).

Fe (9, 30, 50)		
$\lambda$	$n$	$k$
0.589	2.36	1.36
.589	2.18*	1.25*
.589	2.41†	1.41†
.589	2.36†	1.36†

\* (59). † (20).

Steel (34, 51, 53)		
99 Fe + 1 C		
$\lambda$	$n$	$k$
0.227	1.30	1.26
.231	1.32	1.28
.257	1.38	1.35
.298	1.40	1.43
.326	1.37	1.53
.361	1.52	1.63
.400	1.68	1.62
.420	1.79*	1.58*
.440	1.86*	1.55*
.460	1.93†	1.54†
.480	2.07*	1.46*
.500	2.13†	1.46†
.520	2.26*	1.38*
.540	2.30†	1.41†
.580	2.44†	1.36†
.620	2.54†	1.34†
.660	2.64†	1.31†
.700	2.70†	1.31†

\* (52). † (51).

Hg, Liquid (12, 31, 38)		
$\lambda$	$n$	$k$
0.257	0.61*	2.94*
.275	0.62*	3.03*
.298	0.65*	3.10*
.302	0.55†	4.09†
.313	0.44†	5.75†
.325	0.69*	3.35*
.326	0.68	3.32
.361	0.77	3.51
.365	0.64†	4.64†
.398	0.92	3.44
.405	0.79†	4.30†
.436	0.88†	3.94†

Hg.—(Continued)

$\lambda$	$n$	$k$
0.441	1.01	3.39
.468	1.15	3.21
.508	1.31	2.99
.589	1.62	2.71
.630	1.72	2.73

\* (12). † (38).

I (31)		
$\lambda$	$n$	$k$
0.326	1.70	0.49
.361	2.04	.65
.398	2.36	.63
.441	2.81	.54
.468	3.08	.47
.508	3.31	.37
.589	3.34	.17

Ir (57)		
$\lambda$	$n$	$k$
0.578	2.13	2.28
.660	2.40	2.10

K (11, 35)		
$\lambda$	$n$	$k$
0.472	0.070	14.3
.546	.060*	21.5*
.589	.068	22.1
.665	.066	26.8

\* (25).

Mg (9)		
$\lambda$	$n$	$k$
0.589	0.37	11.8
.63	.40	11.5

Crystal axis* $\perp$ (20)		
$\lambda$	$n$	$k$
0.416	0.260	5.95
.440	.290	6.10
.496	.285	6.37
.520	.335	6.97
.560	.337	6.38
.589	.340	6.25
.620	.315	6.97
.650	.323	6.94

Crystal axis* $\parallel$ (20)		
$\lambda$	$n$	$k$
0.416	0.305	4.94
.440	.340	3.87
.496	.365	5.06
.520	.385	5.57
.560	.420	4.62
.589	.390	5.05
.620	.420	5.48
.650	.423	5.18

\* Principal axis  $\perp$  [111] to plane of incidence.

Mn (14, 30, 57)		
$\lambda$	$n$	$k$
0.257	0.661	1.79
.274	0.762	1.67
.297	1.01	1.58
.325	1.03	1.71
.340	1.02	1.75
.347	1.10	1.76
.360	1.16	1.79
.397	1.29	1.83
.414	1.39	1.80
.439	1.54	1.79
.468	1.65	1.71
.479	1.69	1.75
.507	1.84	1.78
.532	1.85	1.77
.578	2.49*	1.56*



Mn.—(Continued)		
$\lambda$	$n$	$k$
0.588	2.25	1.67
.589	2.41†	1.61†
.625	2.23	1.74
.668	2.62	1.55
* (57). † (30).		
MoS <sub>2</sub> , Molybdenite (32)		
0.330	2.22	1.00
.350	2.64	0.98
.370	3.21	.96
.390	3.85	.89
.410	4.00	.81
.430	4.50	.66
.450	4.68	.58
.470	5.00	.47
.500	5.67	.34
Na (11, 35)		
0.435	0.058	31.7
.472	.057	33.3
.546	.052	42.6
.546	.047*	47.3*
.589	.044	55.0
.665	.051	55.0
* (35).		
Nb; see Cb		
Ni (9, 50, 53)		
0.420	1.42	1.79
.460	1.46	1.89
.500	1.54	1.93
.540	1.63	1.97
.580	1.73	1.98
.588	1.58*	2.06*
.589	1.79†	1.86†
.620	1.82	1.99
.660	1.95	1.98
.700	2.03	1.97
* (50). † (30).		
Pb (9, 27); cf. (1)		
0.436	1.63 l*	2.28 l*
.546	2.42 l*	1.84 l*
.579	2.56 l*	1.77 l*
.589	2.01	1.73
.630	1.97	1.74
* (27); l = liquid Pb.		
Pd (57)		
0.578	1.62	2.10
Pt (9, 39, 62)		
0.439	1.63	2.08
.466	1.71	2.11
.477	1.72	2.14
.488	1.76	2.11
.503	1.79	2.15
.517	1.85	2.12
.589	2.07	2.12
.589	2.06*	2.06*
.589	2.03†	1.96†
.630	2.16*	2.06*
.633	2.22	2.10
.665	2.34	2.08
.704	2.43	2.11
* (30). † (30).		

Rb (36)		
$\lambda$	$n$	$k$
0.455	0.137	5.28
.489	.134	6.49
.540	.140	7.97
.589	.131	9.28
.641	.140	10.51
Rh (57)		
0.578	1.54	3.00
.660	1.81	2.94
Sb (9)		
0.589	3.04	1.63
.630	3.17	1.56
Se (21, 31)		
0.257	1.73	0.725
.275	1.82	.736
.298	2.46	.635
.326	2.75	.546
.361	2.65	.518
.398	2.88	.426
.441	2.93	.359
.468	2.94	.320
.508	2.92	.281
.589	2.85	.221
.589	3.2*	
.668	2.79	.161
Crystal axis† ⊥ (33, 49, 58)		
0.30	2.2	0.7
.35	2.6	.6
.40	2.9	.6
.45	3.1	.5
.50	3.2	.4
.55	3.3	.3
.60	3.4	.3
.65	3.4	.3
.70	3.5	.3
Crystal axis†    (33, 49, 58)		
0.30	3.4	0.7
.35	3.6	.6
.40	4.0	.6
.45	4.2	.5
.50	4.3	.4
.55	4.3	.3
.60	4.4	.3
.65	4.5	.3
.70	4.5	.3
* (21). † Principal axis ⊥    to plane of incidence.		
Si (26, 30, 57)		
0.578	3.87	0.12
0.589	4.24*	.114*
1.00 to	4.07†	.095†
2.25		
* (30). † (30).		
Sn (9, 12, 27); cf. (1)		
0.257	1.12	2.98
.275	1.12	2.95
.298	1.04	2.66
.325	0.98	2.45
.347	1.01	2.20
.361	0.91	2.13
.398	0.68	2.82
.425	0.70	3.55

Sn.—(Continued)		
$\lambda$	$n$	$k$
0.436	1.18 l*	3.44 l*
.447	0.72	4.03
.468	0.70	4.44
.480	0.71	4.68
.502	0.78	4.58
.533	0.89	4.41
.546	1.73 l*	3.08 l*
.579	1.77 l*	3.09 l*
.588	1.12	4.03
.589	1.48†	3.55†
.620	1.25	3.83
.630	1.66†	3.30†
.668	1.42	3.53
* Liquid (27); cf. (1). † (30).		
Ta (57)		
0.578	2.05	1.13
Te (33)		
Crystal axis†		
0.300	1.5	0.1
.350	2.0	.2
.400	2.4	.2
.450	2.5	.3
.500	2.6	.4
.550	2.7	.5
.600	2.5	.6
.650	2.0	.5
Crystal axis† ⊥		
0.300	1.9	0.3
.400	2.4	.3
.450	2.9	.4
.500	3.0	.5
.550	3.1	.6
.600	2.9	.6
.650	2.4	.6

V (57)		
$\lambda$	$n$	$k$
0.578	3.03	1.16
W (57)		
0.578	2.76	0.98
Zn (9, 31)		
0.257	0.55	1.10
.275	0.46	2.56
.298	0.47	3.41
.326	0.60	3.72
.361	0.72	3.63
.398	0.85	3.45
.441	0.93	3.40
.468	1.05	3.32
.508	1.41	2.92
.589	1.93	2.41
.589	2.12(9)	2.60(9)
.630	2.36	2.34
.668	2.62	1.94
Crystal axis† ⊥ (20)		
0.455	1.00	3.55
.486	1.35	3.14
.520	1.47	2.94
.560	1.92	2.60
.589	2.58	2.29
.630	2.47	2.47
.650	2.47	2.15
Crystal axis†    (20)		
0.455	0.78	4.58
.486	1.09	3.80
.520	1.32	3.49
.560	1.61	3.08
.589	2.02	2.86
.630	2.27	2.79
.650	2.07	2.60

† Principal axis ⊥ || to plane of incidence.

TABLE 2.—REFRACTION AND ABSORPTION OF ALLOYS

Grouped according to number of components; in each group the arrangement is alphabetical by chemical symbols. At. %, V %, Wt. % = atomic %, volume %, weight %; C = composition.  $J_x = J_0 e^{-4\pi n k x / \lambda_0}$ ;  $x$  and  $\lambda_0$  expressed in same unit. Unit of  $\lambda = 1 \mu = 10^4 \text{ \AA} = 10^{-4} \text{ cm}$ .

Ag-Cu (39)		
$\lambda$	$n$	$k$
$\lambda = 0.589, C = \text{Wt. \% Cu}$		
C		
0	0.20	17.1
3	.25	11.4
6	.52	6.5
10	.49	7.5
30	.36	6.6
50	.31	7.6
72	.24	13.8
80	.42	7.1
90	.51	5.7
95	.64	5.0
100	.62	4.1
Ag-Cu (31)		
$C = 50 \text{ Wt. \% Cu}$		
$\lambda$	$n$	$k$
0.257	0.86	0.94
.275	.89	0.88
.298	.85	1.05
.326	.72	1.40

Ag-Cu.—(Continued)		
$\lambda$	$n$	$k$
0.361	0.63	1.82
.398	.59	2.20
.441	.60	3.26
.468	.58	3.83
.508	.58	3.64
.589	.37	6.68
.668	.32	9.38
Ag-Pt (39)		
$\lambda = 0.589, C = \text{Wt. \% Pt}$		
C	$n$	$k$
0	0.20	17.1
15	0.71	5.92
30	1.15	3.69
40	1.13	2.74
45	1.26	2.42
50	1.57	2.15
90	2.12	1.85
100	2.03	1.96



Ag-Sn (2)		
$\lambda = 0.578, C = \text{Wt. \% Sn}$		
C	n	k
4	1.05	3.79

Ag-Tl (2)		
$\lambda = 0.578, C = \text{Wt. \% Tl}$		
C	n	k
2.73	0.332	12.16
4.76	0.423	10.14

Al-Cu (30)		
$\lambda = 0.589, C = \text{V \% Al}$		
C	n	k
0	0.64	4.08
19	0.80	3.70
36.4	1.32	2.56
51.4	1.97	1.62
57.8	2.24	1.58
76	1.68	2.35
100	1.44	3.64

Bi-Hg, Liquid (27)		
$\lambda = 0.436, C = \text{At. \% Hg}$		
C	n	k
0	1.80	1.79
40	1.59	2.07
100	1.01*	3.39*
$\lambda = 0.546$		
C	n	k
0	2.35	1.63
40	2.24	1.78
100	1.48	2.81*
$\lambda = 0.579$		
C	n	k
0	2.48	1.60
40	2.38	1.68
100	1.62	2.80*

Bi-Pb, Liquid (27)		
$\lambda = 0.436, C = \text{At. \% Pb}$		
C	n	k
0	1.80	1.79
6	1.85	1.70
18	1.82	1.77
26.4	1.73	1.90
48	1.74	1.95
61	1.74	1.98
75	1.78	1.99
86	1.63	2.28
100	1.63	2.28
$\lambda = 0.546$		
C	n	k
0	2.35	1.63
6	2.35	1.64
19	2.44	1.68
26.4	2.44	1.68
48	2.24	1.77
61	2.34	1.79
75	2.32	1.84
86	2.42	1.84
100	2.42	1.84
$\lambda = 0.579$		
C	n	k
0	2.48	1.60
6	2.52	1.59
19	2.48	1.63
26.4	2.56	1.64
48	2.56	1.64
66	2.55	1.67
75	2.62	1.67
86	2.56	1.77
100	2.56	1.77

C-Fe, Steel see Fe, Table 1

Cd-Hg (2)		
$\lambda = 0.578, C = \text{Wt. \% Hg}$		
C	n	k
5.14	1.69	2.75
10	0.79	6.08

Cd-Pb, Liquid (27)		
$\lambda = 0.436, C = \text{At. \% Pb}$		
C	n	k
0	0.39	9.13
12	0.55	6.53
22	0.81	4.61
33.5	1.02	3.74
64	1.27	2.88
79.5	1.52	2.37
100	1.63	2.28

$\lambda = 0.546$		
C	n	k
0	0.76	6.41
12	1.14	4.20
22	1.14	4.20
33.5	1.58	3.07
64	1.92	2.32
79.5	2.05	2.16
100	2.42	1.84

$\lambda = 0.579$		
C	n	k
0	0.82	6.27
12	1.43	3.51
22	1.43	3.51
33.5	1.69	2.98
64	1.99	2.40
79.5	2.21	2.05
100	2.56	1.77

Cu-Fe (30)		
$\lambda = 0.589, C = \text{V \% Fe}$		
C	n	k
0	0.64	4.08
27.6	1.77	1.53
53.4	2.24	1.32
77.6	2.62	1.30
100	2.41	1.41

Cu-Ni (30); cf. (2, 9)		
$\lambda = 0.589, C = \text{V \% Ni}$		
C	n	k
0	0.64	4.08
25	1.61	2.15
40	2.09	1.47
50	2.33	1.55
60	2.12	1.55
75	2.01	1.57
100	1.79	1.85

Cu-Sn, C = Wt. \% Sn		
$\lambda = 0.578 (2)$		
C	n	k
5	0.63	6.66
$\lambda = 0.55 (56)$		
C	n	k
32	1.19	2.4
$\lambda = 0.60 (56)$		
C	n	k
32	1.22	2.7

Cu-Zn (2)		
$\lambda = 0.578, C = \text{Wt. \% Zn}$		
C	n	k
3.11	0.50	8.39
5.0	0.45	9.57

Fe-Mn (30)		
$\lambda = 0.589, C = \text{V \% Mn}$		
C	n	k
0	2.36	1.36
50	2.42	1.53
75	2.43	1.55
100	2.41	1.61

Fe-Ni (30)		
$\lambda = 0.589, C = \text{V \% Ni}$		
C	n	k
0	2.41	1.41
1.7	2.44	1.41
6.2	2.38	1.40
20.0	2.31	1.47
22.8	2.30	1.48
25.8	2.25	1.52
33	2.23	1.50
44.2	2.16	1.63
73	2.01	1.74
100	1.79	1.86

K-Na (35)		
$\lambda = 0.546, C = \text{Wt. \% Na}$		
C	n	k
0.0	0.060	21.5
15.7	0.088	17.6
25.8	0.124	12.8
34.0	0.137	12.5
45.0	0.115	15.6
55.0	0.108	16.8
63.8	0.100	18.5
82.7	0.081	27.2
100.0	0.047	47.3

Ni-Si (30)		
$\lambda = 0.589, C = \text{V \% Si}$		
C	n	k
0	1.79	1.85
16.3	2.04	1.56
29.1	2.35	1.32
39.3	2.61	1.12
47.4	2.87	0.99
100	4.24	0.114

Pb-Sn, Liquid (27)		
$\lambda = 0.436, C = \text{At. \% Sn}$		
C	n	k
0	1.63	2.28
14.5	1.46	2.61
62.5	1.24	3.09
93	1.25	3.18
100	1.18	3.44

Pb-Sn.—(Continued)		
C	n	k
$\lambda = 0.546$		
0	2.42	1.84
14.5	2.00	2.30
62.5	1.91	2.52
93	1.70	3.05
100	1.73	3.08
$\lambda = 0.579$		
0	2.56	1.77
14.5	2.24	2.14
62.5	2.03	2.50
93	1.89	2.81
100	1.77	3.09

Pt-Rh (57)		
$\lambda = 0.578, C = \text{Wt. \% Rh}$		
C	n	k
10.0	1.79	2.35
$\lambda = 0.660$		
10.0	2.08	2.22

Wood's metal (9, 31); cf. (1);  
C = Wt. % 50Bi + 25Pb +  
12.5Sn + 12.5Cd.

$\lambda$	n	k
0.257	0.58	2.68
.275	0.68	2.73
.298	0.76	2.86
.326	0.85	2.81
.361	0.96	2.80
.398	1.14	2.69
.441	1.22	2.67
.468	1.28	2.46
.508	1.53	2.36
.589	1.80	2.24
.589	2.03*	2.29*
.589	2.10 l*	2.15 l*
.668	2.04	2.10

\* (9); l = liquid.

TABLE 3.—REFRACTION AND ABSORPTION BY OPAQUE FILMS OF  
PURE METALSCath, Chem, Elec = film deposited by cathode sputtering,  
by chemical reaction, by electrolysis.  $J_x = J_0 e^{-4\pi n k x / \lambda_0}$ ; x and  $\lambda_0$   
expressed in same unit. Unit of  $\lambda = 1\mu = 10^4\text{\AA} = 10^{-4}\text{ cm}$ .

Ag, Cath (28); cf. (16, 17, 43)

$\lambda$	n	k
0.546	0.168	19.6
0.578	0.172	19.3
Chem (13, 51)		
0.460	0.270*	12.0*
0.500	0.273*	13.0*
0.540	0.279*	14.0*
0.580	0.284*	14.8*
0.620	0.291*	15.5*
0.650	0.19	18.1
0.660	0.299*	16.3
0.700	0.308*	16.9*
0.750	0.16	28.6
0.940	0.15	36.2
1.15	0.23	31.2
1.47	0.36	23.9
2.10	1.00	14.3
2.99	1.39	13.7

Ag, Chem.—(Continued)

$\lambda$	n	k
3.38	2.06	11.1
4.04	2.98	9.5
4.37	4.34	7.4
Chem (51), on glass, light inci-		
dent through the glass		
0.460	0.339	6.90
.500	.343	7.72
.540	.348	8.51
.580	.356	9.26
.620	.365	9.93
.660	.375	10.46
.700	.386	10.96

\* (51).

Au, Cath (28)

$\lambda$	n	k
0.546	0.45	5.36
0.578	0.30	8.93



Au.—(Continued)		
$\lambda$	$n$	$k$
Elec (13, 31, 51)		
0.257	0.92*	1.24*
0.275	1.06*	1.20*
0.298	1.10*	1.25*
0.326	1.26*	1.29*
0.361	1.30*	1.35*
0.398	1.29*	1.41*
0.441	1.18*	1.57*
0.460	1.66	1.10
0.468	1.10*	1.66*
0.480	1.53	1.22
0.500	1.33	1.51
0.520	1.10	1.98
0.540	0.94	2.72
0.560	0.81	3.50
0.580	0.73	4.14
0.600	0.67	4.86
0.620	0.65	5.29
0.640	0.63	5.69
0.660	0.64	5.86
0.670	0.28†	18.0†
0.680	0.62	6.26
0.870	0.21†	26.0†
1.07	0.25†	28.6†
1.41	0.36†	26.0†
1.69	0.40†	28.6†
2.11	0.50†	28.6†
2.87	0.73†	22.0†
3.14	0.80†	23.6†
3.50	0.96†	23.6†
4.13	1.60†	18.0†
4.83	1.83†	18.0†
* (31). † (13).		

Cu, Cath (13, 28, 43, 46)		
0.546	0.901*	2.70*
0.546	0.925†	2.09†
0.546	0.97†	2.76†
0.578	0.515*	4.91*
0.578	0.501†	3.98†
0.810	0.43	9.8
1.03	0.43	13.0
1.27	0.37	19.1
1.53	0.53	15.1
1.77	0.73	13.0
2.28	0.68	16.8
3.05	0.90	15.9
3.25	1.08	15.1
3.59	1.39	13.6
4.20	1.92	11.9
Elec (13, 51)		
0.460	1.57	1.44
0.480	1.53	1.50
0.500	1.50	1.58
0.520	1.43	1.68
0.540	1.38	1.79
0.560	1.27	2.02
0.580	1.07	2.66
0.600	0.98	3.25
0.640	0.96	3.68
0.660	1.00	3.72
0.700	1.03	3.69
0.740	1.25‡	3.6‡
0.900	1.93‡	2.6‡

Cu, Elec.—(Continued)		
$\lambda$	$n$	$k$
1.10	3.09‡	2.0‡
1.32	4.32‡	1.5‡
3.11	4.74‡	1.7‡
3.60	7.12‡	1.3‡
4.61	7.61‡	1.3‡
* (28). † (46). ‡ (43). § (13).		

Fe, Cath (31)		
0.257	1.01	0.874
.275	0.95	0.841
.298	0.92	0.903
.326	0.99	0.923
.361	1.04	1.05
.398	1.17	1.11
.441	1.28	1.07
.468	1.34	1.03
.508	1.38	1.08
.589	1.51	1.08
.668	1.70	1.08

Ir, Cath (13); cf. (43)		
0.860	3.28	1.63
1.16	4.26	1.61
1.57	5.16	1.54
2.77	6.55	1.43
3.36	8.80	1.28
4.60	12.28	1.19

Ni, Cath (28, 31)		
0.257	1.09	1.10
.275	1.09	1.06
.298	1.09	1.04
.326	1.08	1.00
.361	1.08	1.01
.398	1.09	1.08
.441	1.16	1.06
.468	1.17	1.17
.508	1.19	1.29
.546	1.81*	1.57*
.578	1.84*	1.61*
.589	1.30	1.52
.668	1.35	1.61
Elec (31)		
0.257	0.87	1.42
.275	1.12	1.46
.298	1.31	1.39
.326	1.32	1.41
.361	1.28	1.47
.398	1.37	1.70
.441	1.46	1.85
.468	1.44	2.00
.508	1.50	2.06
.589	1.58	2.16
.668	1.74	2.18
* (28)		

Pt, Cath (13, 28); cf. (29, 44)		
0.546	1.83*	2.09*
0.578	1.92*	2.10*
1.00	3.42	1.83
1.52	4.71	1.76
1.97	5.92	1.65
3.29	7.50	1.62
3.41	8.82	1.56
4.65	10.9	1.41

Pt.—(Continued)		
$\lambda$	$n$	$k$
Elec (31)		
0.257	1.17	1.41
.275	1.29	1.51
.298	1.28	1.67
.326	1.28	1.72
.361	1.38	1.77
.398	1.74	1.71
.441	1.94	1.63

Pt, Elec.—(Continued)		
$\lambda$	$n$	$k$
0.468	2.09	1.57
.508	2.29	1.48
.589	2.63	1.35
.668	2.91	1.26
* (28).		
W, Cath (30); cf. (42)		
0.579	2.8	
0.589	3.5	

TABLE 4.—REFRACTION AND ABSORPTION OF TRANSPARENT FILMS OF PURE METALS

Films are deposited by cathode sputtering.  $\tau$  = thickness;  $J_z = J_0 e^{-4\pi n k \tau / \lambda_0}$ ;  $x$  and  $\lambda_0$  expressed in same units. Unit of  $\tau = 1 \mu = 10^{-3} \mu = 10^{-7} \text{ cm}$ ; of  $\lambda = 1 \mu = 10^4 \text{ \AA} = 10^{-4} \text{ cm}$ .

Ag (16), $\lambda = 0.436$		
$\tau$	$n$	$k$
0.9	2.27	0.58
2.4	1.56	0.68
2.8	1.34	1.38
28.6	0.58	3.71
53.2	0.71	2.92
$\lambda = 0.546$		
0.6	4.50	0.067
0.9	4.25	0.45
2.4	3.23	0.45
2.8	2.53	0.78
5.5	2.07	0.83
28.6	1.22	2.25
53.2	0.81	3.23
96.2	0.21	14.9
$\lambda = 0.579$		
53.2	0.90	3.19
$\lambda = 0.622$		
0.9	4.83	0.46
2.8	2.90	0.68

Au (44), $\lambda = 0.500$		
1.0	1.96	0.46
1.5	1.59	0.85
3.4	1.34	1.22
9.2	1.12	1.62
23.1	1.02	1.80
32.2	1.06	1.69
50.3	1.06	1.64
72.6	1.09	1.58
113.2	0.85	1.94
$\lambda = 0.600$		
1.0	2.09	0.40
1.5	2.25	0.89
3.4	1.63	1.64
9.2	0.77	3.74
23.1	0.66	4.39
32.2	0.73	3.75
50.3	0.77	3.48
72.6	0.77	3.43
113.2	0.35	7.12
$\lambda = 0.700$		
1.5	3.31	0.55
3.4	2.14	1.42
9.2	1.13	3.10
23.1	0.58	5.79
32.2	0.63	4.92
50.3	0.63	4.62
113.2	0.20	12.8

Cu (16); cf. (3, 43)		
$\tau$	$n$	$k$
$\lambda = 0.436$		
0.8	3.23	0.15
13.7	1.93	0.47
20.2	1.80	1.10
$\lambda = 0.546$		
0.8	1.96	0.41
13.7	1.50	1.50
20.2	1.45	1.64
37.2	1.26	1.91
40.1	1.23	1.95
44.8	1.13	1.95
$\lambda = 0.622$		
0.8	0.60	1.43
13.7	0.92	1.62

Pd (44), $\lambda = 0.600$		
0.2	3.10	0.58
0.4	3.40	0.20
1.7	2.94	0.57
3.1	2.84	0.65
5.1	2.60	0.82
6.4	2.46	0.89
9.6	2.20	1.05
22.0	2.10	1.24
33.1	2.01	1.41
39.7	1.65	1.60
56.3	1.70	1.76
71.1	1.86	1.56
89.7	1.72	1.66
111.5	1.95	1.39
$\tau = 232 \text{ m}\mu$		
$\lambda$	$n$	$k$
0.500	1.74	1.24
0.550	1.76	1.36
0.600	1.92	1.31
0.650	1.94	1.41
0.700	2.05	1.40

Pt (44), $\lambda = 0.600$		
$\tau$	$n$	$k$
1.4	3.45	0.29
2.6	3.17	0.74
4.9	2.65	1.09
7.0	2.25	1.30
11.7	2.16	1.39
16.8	2.10	1.44
26.0	2.04	1.47



TABLE 5.—REFLECTIVITY OF PURE METALS AND STEEL: NORMAL INCIDENCE ON MASSIVE METAL

$R_0/100 = J_r/J_i$ . For qualitative comparison with speculum metal for  $\lambda = 0.103$  to  $0.160\mu$ , see Gardner (18) for Ag, Al, Au, Cu, Steel, Pt, and Si, and Hulburt (25) for Ni. Unit of  $\lambda = 1\mu = 10^4\text{\AA} = 10^{-4}\text{ cm}$ .

Ag (7, 22)		Au, Polarized light † (Continued)		Cd (5)		0.326 24.9		0 55.5		0.334 58.0	
λ	R <sub>0</sub>	θ	R <sub>  </sub>	λ	R <sub>0</sub>						
0.45	88.0*	40	86.2	1.06	70.8	0.357	27.3	10	55.5	0.365	74.0
0.50	90.0*	60	81.5	1.71	85.0	0.385	28.6	20	57.3	0.405	79.0
0.55	91.5*	70	80.4	3.06	93.0	0.420	32.7	30	59.9	0.436	88.0
0.60	92.7*	80	82.8	5.24	95.9	0.450	37.0	40	63.4	0.546	92.5
0.65	93.5*	85	90.1	6.75	97.0	0.500	43.7	50	68.5		
0.70	94.1*	θ = 60°		9.38	98.4	0.550	47.7	60	74.6	Mg (6, 25)	
0.80	95.1*	λ	R <sub>⊥</sub>	12.03	98.2	0.600	71.8	70	81.1	0.188	13*
0.90	96.0*	0.500	68.3			0.650	80.0	75	86.9	0.200	21*
1.00	96.4	0.540	83.2	Co (5, 25)		0.700	83.4	80	89.5	0.251	32*
1.50	97.3	0.580	90.8	0.188	33*	0.800	88.6	82.5	93.0	0.305	37*
2.00	97.3	0.660	94.3	0.200	37*	1.00	90.1	θ	R <sub>  </sub>	0.357	45*
3.00	97.3	λ	R <sub>  </sub>	0.251	44*	1.50	93.8	0	55.8	0.50	72
4.00	97.7	0.500	33.2	0.305	51*	2.00	95.5	10	54.7	0.60	73
5.00	97.3	0.540	59.5	0.357	54*	3.00	97.1	20	54.1	1.00	74.0
7.00	98.5	0.580	74.3	1.06	67.5	4.00	97.3	30	50.9	1.40	75.0
9.00	98.9	0.660	84.8	1.71	71.5	5.00	97.9	40	47.0	2.00	77.0
11.00	99.0	* From black-body at temperature t, °C.		3.06	76.7	7.00	98.3	50	40.8	2.50	79.0
14.0	98.8	† R <sub>⊥</sub> [R <sub>  </sub> ] = R when electric vector is ⊥ [  ] to plane of incidence; θ = angle of incidence.		3.96	80.7	9.00	98.4	60	34.0	3.00	80.5
				5.24	86.2	11.00	98.4	70	26.2	4.00	83.5
				6.75	92.7	14.00	97.9	75	24.0	5.00	86.0
				8.02	94.8			80	27.0	6.00	88.0
				9.38	96.4			82.5	33.8	7.00	91.0
				10.49	96.8			θ = 60°		8.00	93.0
				12.03	96.6			λ	R <sub>⊥</sub>	9.00	93.0
				* (25).				0.500	73.6	* (25).	
								0.540	74.4		
								0.620	75.4	Mo (6, 25)	
								0.660	75.5	0.188	27*
								λ	R <sub>  </sub>	0.200	32*
								0.500	34.1	0.251	24*
								0.540	33.7	0.305	43*
								0.620	34.3	0.357	41*
								0.660	35.6	0.40	44.0
								* (25).		0.46	44.6
								† (22).		0.50	45.5
								† R <sub>⊥</sub> [R <sub>  </sub> ] = R when electric vector is ⊥ [  ] to plane of incidence; θ = angle of incidence.		0.60	47.6
										0.70	49.8
										0.80	52.3
										1.00	58.2
										1.20	63.6
										1.40	69.0
										1.60	74.2
										2.00	81.6
										2.50	85.5
										3.00	87.6
										3.50	89.2
										4.00	90.5
										5.00	92.0
										6.00	93.0
										8.00	93.7
										10.00	94.5
										12.00	95.2
										* (25)	
										Na (15)	
										0.254	78.0
										0.265	81.0
										0.280	80.0
										0.313	78.0
										0.384	78.0



Na.—(Continued)

$\lambda$	$R_0$
0.365	78.5
0.405	80.5
0.436	87.5
0.546	96.0

Pd (5, 25)

1.06	74.8
1.71	79.3
3.06	87.5
3.96	88.1
5.24	90.4
6.75	93.3
8.02	94.7
9.38	95.3
10.49	96.6
12.03	96.5

Pt (22, 25); cf. (6)

0.188	35*
0.200	38*
0.251	42*
0.305	49*
0.357	51*
9.00	95.4
11.00	95.6
14.00	96.4

\* (25).

Rh (6)

0.500	76.0
0.800	81.0
1.00	84.0
1.40	88.3
2.00	91.0
3.00	92.0
4.00	92.5
5.00	93.0
7.00	93.5
9.00	94.5

Sb (6)

0.600	53
1.00	55
1.60	58
2.00	60
3.00	65
4.00	68
6.00	70
9.00	72

Si (6)

0.500	34
0.600	32
0.800	29
1.00 to 9.00	28

Sn (6)

1.06	54.0
1.71	59.3
3.06	68.6

Sn.—(Continued)

$\lambda$	$R_0$
3.96	71.7
5.24	76.7
6.75	80.3
8.02	83.2
9.38	87.0
10.49	87.0
12.03	86.9

Ta (5, 25)

0.188	13*
0.200	13*
0.251	15*
0.305	29*
0.357	25*
0.50	38
0.60	45.0
0.80	64.5
1.00	78.5
1.20	84.0
1.60	88.0
2.00	90.5
2.50	91.6
3.00	92.3
4.00	93.0
5.00	93.0
7.00	93.5
8.00	93.8
12.00	95.0

\* (25).

Te (6, 25)

0.188	21*
0.200	22*
0.251	23*
0.305	32*
0.357	41*
0.60	49
0.80	48
1.00	49.5
1.20	50
1.60	51
2.00	52
3.00	53
4.00	57
6.00	63
8.00	72
9.00	78

\* (25).

V (6)

0.50	57.0
0.70	58.5
1.00	61.3
1.40	64.5
2.00	69
3.00	74.3
4.00	78.8

V.—(Continued)

$\lambda$	$R_0$
6.00	85
8.00	89.8
9.00	92

W (6, 25, 59)

0.188	14*
0.200	16*
0.251	16*
0.305	25*
0.357	28*
0.40	47.0
0.46	48.2
0.50	49.3
0.60	51.3
0.67	51†
0.80	56.3
0.80	55†
1.00	62.3
1.20	68.2
1.27	70†
1.40	73.8
1.60	78.0
1.90	83†
2.00	84.6
2.50	89.2
2.90	92†
3.00	90.5
3.50	92.0
4.00	92.8
5.00	94.0
6.00	94.6
7.00	95.1
8.00	95.6
9.00	95.5
10.00	95.5
12.00	96.3

\* (25). † (59).

Zn (5, 7)

0.45	54.0*
0.50	55.0*
0.55	56.0*
0.60	57.5*
0.70	61.0*
0.80	61.5*
0.90	55.5*
1.00	49.0*
1.20	74.7*
1.40	85.8*
1.75	92.0*
2.00	94.0*
3.06	95.5
5.24	97.2
6.75	97.2
9.38	98.1
12.03	98.3

\* (7).

TABLE 6.—REFLECTIVITY OF ALLOYS

All compositions expressed in weight %; tabular values are  $R_0$ ;  $R_0/100 = J_r/J_i$ ; unit of  $\lambda = 1\mu = 10^4\text{\AA} = 10^{-4}\text{ cm}$ 

$\lambda$	1	2	3	4	5	6	7	8
0.188					23			
0.200					25			
0.251	25	67.0			29.9		35.8	
0.288	29	70.6			37.7		37.1	
0.305	31	72.2			41.7		37.2	
0.326	33	75.5					39.3	
0.357	37	81.2			51.0		43.3	
0.385	41	83.9			53.1		44.3	
0.420	44	83.3			56.4		47.2	
0.450	46	83.4	63.5		60.0	56.5	49.2	
0.500	48	83.3	65.8		63.2	57.8	49.3	
0.550	52	82.7	68.3		64.0	59.0	48.3	
0.600		83.0	70.1		64.3	60.2	47.5	
0.650		82.1	71.0	70.0	65.4	61.8	49.7	
0.700		83.3	71.8	71.2	66.8	63.7	54.9	
0.800		84.3	73.0			67.2	63.1	71.1
1.00		84.1	74.0	72.4	70.5	72.3	69.8	74.3
1.50		85.5	75.3	77.8	75.0	78.2	79.1	78.1
2.00		86.7	76.8	82.3	80.4	83.8	82.3	87.0
3.00		87.4	80.0	85.6	86.2	88.7	85.8	90.1
4.00		88.7	82.8	88.3	88.5	91.0	87.1	91.9
5.00		89.0		89.5	89.1		87.3	92.6
7.00		90.0		92.7	90.1		88.6	93.6
9.00		90.9		93.0	92.2		90.3	
11.00		90.7		93.4	92.9		90.2	
14.00		92.2		94.2	93.6		90.3	

1. Al-Cu, Duralumin (8); 94.19 Al + 4.20 Cu + 0.37 Fe + 0.51 Mn + 0.54 Mg + 0.19 Si.

2. Al-Mg, Mach's mirror magnalium (22); 69 Al + 31 Mg. C-Fe Steel; see Fe, Table 5.

3. Co-Cr, Stellite (7); secret composition.

4. Cu-Ni, Constantan (22); 60 Cu + 40 Ni.

5. Cu-Sn, Speculum metal; Ross's metal (22); 68 Cu + 32 Sn.

6. Cu-Fe-Ni, Monel metal (7); 68 to 70 Ni + 1.5 Fe + 30.5 to 28.5 Cu.

7. Cu-Fe-Ni-Sn, Brandes and Schumann alloy (22); 32 Cu + 34 Sn + 29 Ni + 5 Fe.

8. Cu-Ni-Zn, German silver (41); 52 Cu + 26 Zn + 22 Ni.

TABLE 7.—REFLECTIVITY OF SULFIDES WHICH SHOW METALLIC REFLECTION (5, 8, 54)

FeS<sub>2</sub> = Pyrites, MoS<sub>2</sub> = Molybdenite, PbS = Galena, Sb<sub>2</sub>S<sub>3</sub> = Stibnite;  $R_0/100 = J_r/J_i$ ; unit of  $\lambda = 1\mu = 10^4\text{\AA} = 10^{-4}\text{ cm}$ 

$\lambda$	FeS <sub>2</sub>	MoS <sub>2</sub>	PbS	Sb <sub>2</sub> S <sub>3</sub>
0.24	49	53	40	52
0.25	48	57	40	51
0.27	48	56	42	57
0.30	50	50	49	61
0.35	46	48	48	60
0.40	38	50	41	54
0.45	44	53	37	51
0.50	52	47	34	49
0.55	53	42	37†	42*
0.60	54*	42†	36†	41*
0.70	60*	42†	42†	44†
1.0	62†	39†	35†	40†
3.0	62†	39†	31†	37†
6.0	62†		31†	37†
11.0	62†		31†	37†
13.0	62†			30†

\* (54). † (5).



TABLE 8.—REFLECTIVITY OF OPAQUE FILMS OF PURE METALS

$$R_0/100 = J_r/J_i; \text{ unit of } \lambda = 1\mu = 10^4\text{\AA} = 10^{-4}\text{ cm}$$

Deposited by cathode sputtering (25); tabular values =  $R_0$ 

$\lambda$	Ag*	Al†	Au	Bi	Cd	Cu*
0.188	22	25	17	17	20	23
0.200	25	31	20	18	23	31
0.251	33	53	25	24	36	26
0.305	17	64	36	30	49	29
0.357	67	70	45	36	60	32

$\lambda$	Ni*	Pb	Sb	Si	Sn	Zn
0.188	35	16	31	64	8	17
0.200	44	18	33	73	9	22
0.251	38	20	53	75	17	39
0.305	46	22	64	73	21	48
0.357	49	26	71	60	27	51

\* Ag is chemically, and Cu and Ni are electrolytically deposited; see below for other data. † Cf. (25).

Deposited by cathode sputtering (22); tabular values =  $R_0$ 

$\lambda$	Ag	Au	Pt	$\lambda$	Ag	Au	Pt
0.65	94.6	89.1	63.8	7.00	98.3	95.7	93.0
1.00	95.5	93.6	70.4	8.00	98.1	96.1	92.5
1.50		94.8	75.3	9.00	98.1	96.1	92.5
2.00	96.8	94.9	79.8	10.00	98.5	96.4	93.1
3.00	97.4	95.6	88.5	11.00	98.8	96.5	92.7
4.00	97.6	96.0	91.6	12.00	98.1	97.2	94.9
5.00	97.3	95.7	90.8	14.00		96.7	94.7

Chemically (Chem) and electrolytically (Elec) deposited

Ag, Chem (22, 25, 51)		Ag.—(Continued) Chem on glass† (51)		Ag, Chem (Lacquered) (7)	
$\lambda$	$R_0$	$\lambda$	$R_0$	$\lambda$	$R_0$
0.188	22*	0.460	81.0	Before exposure*	
0.200	25*	0.500	84.0	0.55	68.6
0.251	34.1	0.540	86.2	0.60	73.5
0.288	21.2	0.580	88.5	0.65	77.0
0.305	9.1	0.620	90.2	0.70	79.8
0.316	4.2	0.660	91.9	0.75	81.9
0.326	14.6	0.700	93.0	1.00	87.8
0.338	55.5	$\lambda$	$R_{0f}$ (41)§	1.25	90.8
0.357	74.5	0.779	92.0	1.50	93.2
0.385	81.4	0.910	94.4	2.00	95.0
0.420	86.6	1.096	96.0	After exposure*	
0.450	90.5	1.329	97.3	0.55	62.0
0.460	90.5†	1.718	97.5	0.60	68.7
0.500	92.7†	2.204	98.0	0.65	73.8
0.500	91.3	3.842	98.0	0.70	77.5
0.540	93.0†	4.810	98.1	0.75	80.5
0.550	92.7	6.264	98.2	* Exposed six hours to light from a 15 amp. carbon arc 0.5 meter away. Deterioration due presumably to the effect of ultra-violet light on the lacquer.	
0.580	94.8†	7.737	98.5	Au, Elec (22, 51)	
0.600	92.6	$\lambda$	$R_{0f}$ (41)§	0.251	38.8
0.620	95.0†	0.779	85.2	0.288	34.0
0.650	93.5	0.910	86.5	0.305	31.8
0.660	95.2†	1.096	88.3	0.326	28.6
0.700	94.6	1.329	89.5	0.357	27.9
0.700	95.3†	1.718	90.9	0.385	27.1
0.800	96.3	2.204	91.9	0.420	29.3
1.00	96.6	3.842	93.6	0.450	33.1
1.50	97.9	4.810	94.1	0.460	37.0*
3.00	98.1	6.264	95.5		
4.00	98.5	7.737	96.2		
5.00	98.1	* (25). † (51). ‡ Light incident on glass side.			
7.00	98.5	§ $R_{0f}/R_0 = R$ for new (old) film.			
14.00	98.8				

Au, Elec.—(Cont'd.)

$\lambda$	$R_0$
0.480	38.0*
0.500	43.0*
0.520	53.0*
0.540	61.8*
0.560	70.8*
0.580	75.8*
0.600	79.2*
0.620	81.2*
0.640	84.0*
0.660	85.2*
0.680	85.3*
0.700	92.3
0.800	94.9
1.50	97.3
2.00	96.8
4.00	96.9
5.00	97.0
7.00	98.3
9.00	98.0
11.00	98.3
14.00	97.9

\* (51).

Au, Chem (22)

$\lambda$	$R_0$
0.65	89.6
0.70	91.3
1.00	94.7
1.50	96.7
2.00	96.5
3.00	96.7
4.00	97.2
5.00	96.9
7.00	97.3
9.00	96.7
11.00	97.7
14.00	98.7

Cu, Elec (25, 51)

$\lambda$	$R_0$
0.188	23*
0.200	31*
0.251	26*
0.305	29*
0.357	32*
0.460	46.0
0.480	48.0
0.500	49.0
0.520	51.2
0.540	54.0
0.560	57.5
0.580	65.5
0.600	71.0
0.640	76.5
0.660	77.7
0.700	78.6

\* (25).

Ni, Elec (22, 25)

$\lambda$	$R_0$
0.188	35*
0.200	44*
0.251	37.8
0.288	42.7
0.305	44.2
0.326	45.2
0.338	46.5
0.357	48.8
0.385	49.6
0.420	56.6
0.450	59.4
0.500	60.8
0.550	62.6
0.600	64.9
0.700	68.8
0.800	69.6

Ni, Elec.—(Cont'd.)

$\lambda$	$R_0$
1.000	72.0
2.00	83.5
3.00	88.7
5.00	94.4
7.00	94.3
9.00	95.6
11.00	95.9
14.00	97.2

\* (25).

Pt, Elec (22)

$\lambda$	$R_0$
0.251	33.8
0.288	38.8
0.305	39.8
0.326	41.4
0.357	43.4
0.385	45.4
0.420	51.8
0.450	54.7
0.500	58.4
0.550	61.1
0.600	64.2
0.650	66.5
0.700	69.0
0.800	70.3
1.00	72.9
1.50	77.7
2.00	80.6
3.00	88.8
4.00	91.5
5.00	93.5
7.00	95.5

TABLE 9.—TRANSMISSION, REFLECTION, AND ABSORPTION OF THIN FILMS OF PURE METALS

 $R_0/100 = J_r/J_i$ ;  $T/100 = J_t/J_i$ ;  $A = 100 - (R_0 + T)$ ;  $\tau$  = thickness of film. Ag is chemically deposited on glass, Au and Pt are deposited on quartz ( $\text{SiO}_2$ ) by cathode sputtering. Unit of  $\tau = 1\text{m}\mu = 10^{-3}\mu = 10^{-7}\text{ cm}$ ; of  $\lambda = 1\mu = 10^4\text{\AA} = 10^{-4}\text{ cm}$ .

$\tau$	48.6	79.0	100.4
$\lambda$	Ag (23); cf. (24, 52), T		
0.221	7.0	2.5	
0.251	6.8	1.20	
0.288	10.2	2.92	1.32
0.305	23.2	10.3	4.6
0.310	33.4	14.6	8.2
0.316	39.8	26.7	19.7
0.321	44.1	31.6	22.5
0.326	39.4	25.4	16.9
0.332	27.6	15.9	10.0
0.338	20.7	10.2	3.63
0.357	11.8	4.16	0.81
0.385	9.90	2.38	0.43
0.420	8.85	1.30	0.32
0.450	6.80	0.84	0.24
0.500	5.32	0.40	0.10
0.55	4.12	0.27	0.076
0.60	3.36	0.142	0.050
0.65	2.78	0.106	0.034
0.7	2.55	0.079	0.025



TABLE 9.—(Continued)

$\tau$	48.6	79.0	100.4
$\lambda$	Ag (23); cf. (24, 52), $T$		
0.8	1.95	0.052	0.017
1.0	1.40	0.029	0.010
1.2	1.29	0.024	0.006
1.5	1.16	0.036	0.007

$\tau$	53.3	73.2	101.1	20.9	51.5	89.9
$\lambda$	Au (23), $T$			Pt (23), $T$		
0.326	2.87	0.91		7.7		
0.357	3.98	1.06	0.306	7.6	0.49	
0.385	4.15	1.41	0.309	7.6	0.51	
0.42	5.10	1.74	0.440	7.1	0.57	
0.45	6.62	2.80	0.685	7.0	0.54	0.027
0.50	10.03	4.12	0.929	6.7	0.52	0.021
0.55	6.66	2.42	0.519	6.1	0.55	0.022
0.60	3.97	1.38	0.283	5.9	0.51	0.024
0.65	3.02	0.726	0.202	5.8	0.51	0.023
0.7	2.31	0.555	0.172	5.6	0.52	0.021
0.8	1.67	0.288	0.101	5.1	0.49	0.020
1.0	1.48	0.227	0.040	4.2	0.53	0.019
1.2	1.01	0.127	0.027	4.0	0.50	0.022
1.5	0.639	0.074	0.016	4.1	0.50	0.028
2.0	0.285	0.039		3.9	0.52	0.038
2.5	0.159	0.031		3.6	0.50	0.041

Pt (40), $\lambda = 0.300$						
$\tau$	$R_f^*$	$R_g^*$	$T$	$A_f^*$	$A_g^*$	
0	7.9	7.9	82.6	0	0	
1.0	9.9	5.8	67.4	15.1	21.0	
2.7	12.8	5.0	53.6	27.2	38.4	
4.2	15.7	6.0	46.9	31.6	45.9	
10	25.8	11.7	24.7	46.1	62.8	
15	28.1	14.7	19.2	50.0	65.2	
22	28.6	19.4	9.1	60.9	70.5	
50	26.4	19.3	0.5	73.0	80.6	

Pt (40), $\lambda = 0.400$					
$\tau$	$R_f^*$	$R_g^*$	$T$	$A_f^*$	$A_g^*$
0	9.2	9.2	91.5	0	0
1.0	10.8	7.2	80.8	8.4	12.0
2.7	13.2	5.4	65.0	21.8	29.6
4.2	17.2	5.7	54.8	28.0	39.5
10	29.5	13.2	30.0	40.5	56.8
15	41.7	21.3	19.1	39.2	59.6
22	47.5	33.4	10.0	42.5	56.6
50	49.8	34.2	0.5	49.7	65.3

\*  $R_f, A_f [R_g, A_g]$  = value of  $R, A$  when light is incident on film [on quartz] side of plate.

## LITERATURE

(For a key to the periodicals see end of volume)

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- (10) Drude, *8*, 64: 159; 98. (11) Duncan and Duncan, *2*, 1: 294; 13. (12) Erochin, *8*, 39: 213; 12. (13) Försterling and Fréedericks, *8*, 40: 201; 13. (14) Fréedericks, *8*, 34: 780; 11. (15) Frehafer, *2*, 15: 110; 20. (16) Fritze, *8*, 47: 763; 15. (17) Galli and Försterling, *188*, 1911 I: 58. (18) Gardner, *21*, 45: 30; 17. (19) Gaubert, *34*, 177: 1123; 23.
- (20) Graber, *2*, 26: 380; 25. (21) Gripenberg, *63*, 14: 123; 13. (22) Hagen and Rubens, *8*, 1: 352; 00. *8*: 1; 02. 11: 873; 03. (23) Hagen and Rubens, *8*, 8: 432; 02. (24) Hartley, *178* (7th) 9: 88; 10. (25) Hulburt, *21*, 42: 205; 15. (26) Ingersoll and Littleton, *2*, 31: 489; 10. (27) Kent, *2*, 14: 459; 19. (27.1) Ketteler, *Theoretische Optik*, p. 122; 1885. (28) Lauch, *8*, 74: 55; 24. (29) Lewis and Hardy, *2*, 14: 272; 19.
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- (40) Partsch and Hallwachs, *8*, 41: 247; 13. (41) Paschen, *8*, 4: 304; 01. (42) Pirani, *63*, 13: 753; 12. (43) Planck, *63*, 15: 563; 14. (44) Pogány, *8*, 49: 531; 16. (45) Quinke, *8*, Jubelband: 336; 74. (45.1) Schuster, *Theory of Optics*, p. 236; 1904. (46) Rother and Lauch, *63*, 24: 462; 23. (47) Seuffleben and Benedict, *8*, 54: 65; 17. (48) Shea, *8*, 47: 177; 92. (49) Skinner, *2*, 9: 148; 17.
- (50) Statescu, *8*, 33: 1032; 10. (51) Tate, *8*, 34: 321; 12. (52) Tear, *2*, 23: 641; 24. (53) Tool, *8*, 31: 1; 10. (54) Tyndall, *8*, 31: 162; 23. (55) Uljanin, *63*, 11: 784; 10. (56) Voigt, *8*, 23: 104; 84. (57) von Wartenberg, *88*, 12: 105; 10. (58) Weld, *48*, 6: 67; 22. (59) Weniger and Pfund, *143*, 183: 354; 17.
- (60) Wheeler, *12*, 35: 491; 13. (61) Wilsey, *2*, 8: 391; 16. (62) Zakrsewski, *180*, 3: 77; 10.

## REFLECTIVITY: NON-METALS

E. P. T. TYNDALL

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TABLE 1.—SPECULAR REFLECTIVITY

Tabular values are  $R = 100I_r/I_i$ ;  $I_r$  = intensity of radiation specularly reflected when intensity of incident radiation is  $I_i$ .  $\lambda_m$  = wave-length at which  $R$  is a local maximum,  $R_m$  = value of  $R$

at  $\lambda_m$ ;  $\parallel_o, \parallel_a, \parallel_b, \parallel_c, [\perp_o]$  = incident light is plane polarized with electric vector parallel to optic axis, to  $a, b, c$  crystallographic axis [ $\perp$  to optic axis].  $\longrightarrow$  [—] indicates that  $dR/d\lambda$  has the same sign [is essentially zero] throughout the region covered by the symbol; { indicates that  $R$  lies between the values so connected. In most cases, angle of incidence is nearly 0.

Table is spectrally subdivided; elementary substances are indicated by their symbols, others by the following key numbers ( $N_k$ ):

$N_k$	Substance	$N_k$	Substance
1 <sub>i</sub>	H <sub>2</sub> O, Water	6	CS <sub>2</sub>
1 <sub>i</sub>	H <sub>2</sub> O, Ice	7	CH <sub>3</sub> OH, Methyl alcohol
2	H <sub>2</sub> SO <sub>4</sub>	8	C <sub>2</sub> H <sub>5</sub> OH, Ethyl alcohol
3	NH <sub>4</sub> Cl	9	C <sub>3</sub> H <sub>8</sub> O <sub>3</sub> , Glycerol
4	NH <sub>4</sub> Br	10	C <sub>6</sub> H <sub>6</sub> , Benzene
5	Sb <sub>2</sub> S <sub>3</sub> , Stibnite	11	C <sub>7</sub> H <sub>8</sub> , Toluene



N <sub>k</sub>	Substance	N <sub>k</sub>	Substance	N <sub>k</sub>	Substance	N <sub>k</sub>	Substance
12	C <sub>6</sub> H <sub>10</sub> , Xylene	24	(CuOH) <sub>2</sub> CO <sub>3</sub> , Malachite	37	BaSO <sub>4</sub> , Barite	46	Mica (muscovite)
13	C <sub>6</sub> H <sub>5</sub> O, Cinnamic aldehyde	25	Fe <sub>2</sub> O <sub>3</sub> , Hematite	38	BaCO <sub>3</sub> , Witherite	47	Porcelain
14	C <sub>10</sub> H <sub>7</sub> Br, $\alpha$ -Bromonaphthalene	26	Fe <sub>3</sub> O <sub>4</sub> , Magnetite	39	BaHgI <sub>4</sub> ·5H <sub>2</sub> O	48	Tourmaline
	SiO <sub>2</sub> , (see Vol. VI)	27	FeS <sub>2</sub> , Pyrites	40	NaCl, Rock salt	49	Cassia oil
15	PbCl <sub>2</sub>	28	FeCO <sub>3</sub> , Siderite	41	NaNO <sub>3</sub>	50	Collodion
16	PbS, Galena	29	(Fe,Ni)S, Pentlandite		LiNa(SeO <sub>4</sub> )	51	Kerosene
17	PbSO <sub>4</sub> , Anglesite		Co(NH <sub>4</sub> ) <sub>2</sub> (SeO <sub>4</sub> ) <sub>2</sub>	42	KCl, Sylvite	52	Naphtha
18	Pb(NO <sub>3</sub> ) <sub>2</sub>		Ni(NH <sub>4</sub> ) <sub>2</sub> (SeO <sub>4</sub> ) <sub>2</sub>	43	KBr	53	Paraffin
19	ZnS, Sphalerite	30	MoS <sub>2</sub> , Molybdenite	44	KI	54	Paraffin oil
	ZnSeO <sub>4</sub>	31	Al <sub>2</sub> (SO <sub>4</sub> ) <sub>3</sub> ·(NH <sub>4</sub> ) <sub>2</sub> SO <sub>4</sub> ·24H <sub>2</sub> O, Ammonium alum		NiK <sub>2</sub> (SeO <sub>4</sub> ) <sub>2</sub>	55	Vaseline (melted)
20	(ZnFe)S, Zinc blende	32	CaF <sub>2</sub> , Fluorite	45	Carborundum		
21	ZnCO <sub>3</sub> , Smithsonite	33	CaCO <sub>3</sub> , Aragonite				
22	CuS, Covellite	34	CaCO <sub>3</sub> , Calcite				
23	Cu <sub>2</sub> S, Chalcocite	35	SrSO <sub>4</sub> , Celestite				
		36	SrCO <sub>3</sub> , Strontianite				

Additional data: (a) Infra-red: Aniline dyes (29), esters and salts of organic acids (22), inorganic salts (82). (b) Aqueous solutions: Nitrides ( $\lambda = 1$  to  $10\mu$ ) (4), inorganic salts (22), effect of chlorides, nitrates, and sulfates in shifting the water maximum near  $\lambda = 3\mu$  (5).

Unit of  $\lambda = 1\mu = 10^4 \text{ \AA} = 10^{-4} \text{ cm}$

$\lambda$	Br	C*	Te	5	6	8	9	10	12	13	14	16	25
0.185													
0.20						3.7	5.5		6.0				
0.21	<4				6.0						6.0		
0.23		21			9.0						9.0		
0.25				50	4.0					0.5	6.0	40	
0.27					1.0					2.0	2.0		
0.29										4.0			
0.31				63						2.0			
0.32													
0.33										0.8		50	
0.40						2.0	4.0	4.0	4.0			40	
0.44				40								45	
0.45	<4		30	50									
0.546		17	30										
0.600			30									40	25
0.645				40								45	
0.72				50									
0.75													
Lit.	(27)	(53)	(81, 88)	(12, 15, 18, 32, 87)	(27, 42, 49)	(49)	(49)	(49)	(49)	(27, 42, 49)	(27, 42, 49)	(12, 15, 32, 87)	(12, 32)

$\lambda$	27	30	32	34	39	40	49	51	52	53	54	55
0.185			8†	13		8						
0.20												
0.21					<4							
0.23		54										
0.25	47	58					0.5					
0.27							2.0					
0.29							4.0					
0.31							2.0					
0.32	50											
0.33		48			<4		0.8					
0.40	39							2.2	2.2	2.5	2.2	2.5
0.44	43											
0.45		59										
0.546	53	41†										
0.600	53	45†	3‡									
0.645		43†										
0.72	62	51†										
0.75		47	3									
Lit.	(12, 15, 33, 87)	(13, 15, 16, 18, 33, 87)	(47)	(36)	(27, 42, 49)	(36)	(27, 42, 49)	(49)	(49)	(49)	(49)	(49)



## INTERNATIONAL CRITICAL TABLES

TABLE 1.—(Continued)

 $\lambda = 1$  to  $21\mu$ ; incident light unpolarized; for 1, 7, 8, 10, 11, 34, 45, 46, 47, 48, see *infra*

$\lambda$	C*	S	5	16	19	22	23	25	26	27	29	30	32	50
1	16.5		40	30	10	45	15	12	5	30	15	30	3	
3		8					↓							
6							50							10
7							↓						3	10
10			40				56							
11							↓							
12					10					30		30		
13														
14		8		30		76	56	12	38		48			
19	16.5													
Lit.	(63)	(13, 70, 74)	(12, 15, 18, 32, 87)	(12, 15, 32, 87)	(12, 18)	(13)	(13)	(12, 32)	(12)	(12, 15, 33, 87)	(13)	(13, 15, 16, 18, 33, 87)	(47)	(86)

$\lambda$	1 <sub>i</sub>	1 <sub>e</sub>	7	8	10	11
Lit.	(3, 9, 22, 72, 73)	(8)	(3)	(3, 72)	(3)	(3)
1.0	1.98	1.72	1.95	2.25	3.85	3.90
1.5	1.95	1.62	1.95	2.20	3.81	3.90
2.0	1.74	1.62	1.85	2.05	3.75	3.85
2.4	1.45	1.13	1.77	1.82	3.55	
2.6	1.25	0.73		1.67	3.35	3.70
2.8	1.35	0.70	1.35	1.45	3.40	3.60
3.0	3.40	1.60	1.95	1.75	3.60	3.80
3.2	4.10	5.10	2.05	2.10	3.35	3.65
3.4	3.25	3.90	1.80	2.00	3.45	3.55
3.5	2.95	2.81	1.92	2.12	3.67	3.77
4.0	2.20	1.75	2.15	2.50	4.00	3.95
4.5	2.14	(22)	2.15	2.60	3.84	3.90
5.0	2.00		2.15	2.40		3.90
5.5	1.68	1 <sub>i</sub>		2.20		3.60
5.6	1.67	1 <sub>i</sub> = 50° = 17				
5.8	1.40					3.80
5.9	1.50					
6.0	2.00			2.05		
6.1	2.28					
6.2	2.46					
6.3	2.34					
6.5	2.10			2.00		
7.0	1.95	3.25		2.00		
7.5	1.75			2.03		
8.0	1.67	3.20		2.20		
8.5	1.60			2.30		
9.0	1.44	2.50		1.70		
9.5	1.24			2.05		
10.0	0.95	2.10		3.03		
10.5	0.85			10.75		
11.0	0.75	1.80		2.40		
11.5	1.10			2.70		
12.0	2.00	2.80		2.80		
12.5	2.00			2.65		
13.0	3.10	4.70		2.85		
13.5	3.40					
14.0	4.10	6.65		3.00		
14.5	4.80					
15.0	5.30	8.20		3.00		
15.5	5.4					
16.0	5.3	8.7		3.0		
16.5	6.0					
17.0	6.6	9.8		2.8		
17.5	6.9					
18.0	6.7	11.3		2.9		

$\lambda$	1 <sub>i</sub>	1 <sub>i</sub> ; $\angle i = 50^\circ$	7	8	10	11
Lit.	(3, 9, 22, 72, 73)	(22)	(3)	(3, 72)	(3)	(3)
18.5	7.5	13.7		2.9		
19.0	8.4					
20.0	8.9					
21.0	8.2					

$\lambda$	34 <sub>i</sub>	34 <sub>e</sub>	45	46	47	48 <sub>i</sub>	48 <sub>e</sub>
1.0			15.0			5.9	5.5
2.0	25.0	21.0				5.7	5.5
2.5						5.6	5.3
3.0	17.0	20.0				5.5	5.7
4.0	13.0	17.0	17.0		1.0	4.9	5.1
5.0	11.0	15.0				4.2	4.5
6.0	3.0	11.0	18.0	3.0	1.0	3.3	3.8
6.5	90.0	11.5		3.5		1.0	3.4
7.0	95.0	9.0		2.0		0.5	2.7
7.5	45.0	9.0		1.5		17.0	3.0
8.0	32.0	9.0	18.0	1.0	0.5	12.0	1.0
8.5				4.0	9.0	3.0	2.0
9.0	21.0	8.0	17.0	35.0	13.0	12.0	37.0
9.25				38.0	16.0	11.0	21.0
9.5			14.0	29.0	13.0	30.0	30.0
9.75				40.0		38.0	25.0
10.0	22.0	7.0	7.0	27.0	8.0	40.0	20.0
10.25			6.0				
10.5			32.0	13.0	7.0	25.0	17.0
11.0	26.0	2.0	80.0	10.0	5.5	15.0	8.0
11.25	27.0	89.0					
11.5		50.0	94.0				
12.0	24.0	17.0	98.0		2.0	9.0	2.0
12.5			91.0			8.0	25.0
13.0	18.0	13.0	63.0			5.0	24.0
13.5			55.0			10.0	2.0
14.0	15.0	8.0	53.0			7.0	30.0
14.25	25.0	8.0				3.0	39.0
14.5	22.0	11.0					
15.0						2.0	15.0
Lit.	(52)	(52)	(13)	(12, 13)	(13)	(13, 63)	(13, 63)

\* Diamond.

† (36).

‡ 41, 45, 43, 51 correspond to  $\lambda = 0.590, 0.610, 0.640, 0.69$ ;  $\lambda_m$  at 0.250, 0.450, 0.610, 0.690 $\mu$ . At  $-160^\circ\text{C}$ ,  $\lambda_m$  shifted from 0.61 and 0.69 to 0.595 and 0.655 $\mu$ , and maxima are enhanced.§ R = 3 from  $\lambda = 0.6\mu$  to  $\lambda = 7.0$ .

|| o = ordinary, e = extraordinary ray.



$\lambda = 1$  to  $21\mu$ ; incident light polarized (79)

Substance		$\lambda_m$	$R_m$	Substance		$\lambda_m$	$R_m$
ZnSeO <sub>4</sub> .....	<sub>o</sub>	11.43	30	Ni(NH <sub>4</sub> ) <sub>2</sub> (SeO <sub>4</sub> ) <sub>2</sub> —(Cont'd).....	<sub>o</sub>	11.15	5
ZnSeO <sub>4</sub> .....	⊥ <sub>o</sub>	11.48	18	LiNaSeO <sub>4</sub> .....	<sub>o</sub>	11.42	13
Co(NH <sub>4</sub> ) <sub>2</sub> (SeO <sub>4</sub> ) <sub>2</sub> .....	<sub>o</sub>	11.56	9		⊥ <sub>o</sub>	11.30	19
	<sub>b</sub>	11.22	6	NiK <sub>2</sub> (SeO <sub>4</sub> ) <sub>2</sub> .....	<sub>a</sub>	11.32	15
	<sub>c</sub>	11.12	5		<sub>b</sub>	11.56	17
Ni(NH <sub>4</sub> ) <sub>2</sub> (SeO <sub>4</sub> ) <sub>2</sub> .....	<sub>o</sub>	11.42	9		<sub>c</sub>	11.18	10
	<sub>b</sub>	11.30	6				

 $\lambda = 22$  to  $310\mu$ ; incident light not polarized

$\lambda =$	22	23	27	33	39	52	63	83	94	117	310	Lit.
8		11.1				9.2						(13, 70, 74)
1		6.5		7.2		9.3	10.6	10.9	11.1	12.7**	15.1**	(69)
2		8.8		7.9		16.9	18.7	17.7	17.7	18.4	21.7	(69)
3		3.8		3.1		79.5	54.7	32.3	26.3	23.4	19.8	(69)
4		6.0		3.8		55.1	66.4	41.5	28.8	24.4	21.1	(69)
9		5.8		5.5		5.2	6.3	7.5		8.5	9.4	(69)
15		10.2		6.9		23.3	43.2	61.8	71.4	58.9	51.8	(69)
18	6.9		6.2	5.5	3.1	5.0	29.4	63.7	55.8	50.8	36.9	(38)
20	7.2		35.4	73.7	51.9	30.3	27.7	25.5	25.0	24.4	23.5	(38)
24	8.5			32.4	23.6	20.0	23.5	24.2	24.0	22.2††	20.8	(38)
31	6.5		4.4	5.7	9.2	18.9	18.0	16.0	15.1	17.7	17.8	(38)
32		55.3		83.0		30.0	25.2	21.6	20.4	20.6	19.9	(69)
40		2.1		1.7		30.2	64.5	27.5	24.3	19.9	17.9	(69)
42		2.3		1.6		39.9	80.0	37.5	24.4	17.4	14.0	(69)
43		3.8		3.2		2.2	18.0	82.8	56.3	21.9	14.9	(69)
44		5.6		4.4		2.2	2.3	30.2	75.0	23.0	15.8	(69)

 $\lambda = 22$  to  $310\mu$ ; incident light plane polarized

$\lambda =$	22	27	33	39	52	63	83	94	110	117	310	Lit.
17    <sub>b</sub>	3.2		43.7	36.2	32.8	20.5	18.5		17.4		17.2	(37)
17    <sub>o</sub>	2.5		55.4	54.9	35.3	22.9	18.7		18.5		18.3	(37)
21    <sub>o</sub>	2.2	15.4	20.4	29.0	79.0	75.9	41.5	31.9		29.6	25.7	(38)
21 ⊥ <sub>o</sub>	3.7	21.7	45.5	32.6	59.5	50.4	33.8	31.7		29.5	25.4	(38)
23    <sub>o</sub>	5.7	30.8	20.2	30.2	69.7	41.5	25.7	22.5		21.1	17.7	(38)
23 ⊥ <sub>o</sub>	5.5	42.4	46.5	31.0	39.1	31.7	25.9	24.3		23.5	22.3	(38)
33    <sub>o</sub>	0.84		60.3	66.0	44.3	28.8	22.9	22.7	19.9		19.7	(37)
33    <sub>b</sub>	1.5		67.1	71.8	51.2	27.4	21.4	27.7	28.8		27.9	(37)
33    <sub>c</sub>	1.9		62.5	51.7	42.1	29.2	24.2	24.7	22.4		21.8	(37)
34    <sub>o</sub>			50.4	29.5	8.2	2.2	48.4	80.8		48.3	28.9	(37)
34 ⊥ <sub>o</sub>			64.5	43.2	25.8	15.9	26.2	58.0		38.5	27.2	(37)
35    <sub>o</sub>	5.4		8.8	30.6	57.2	33.4	54.3	44.1	31.3		25.6	(37)
35    <sub>b</sub>	6.2		6.1	14.4	57.5	66.7	15.5	13.9	53.7		54.5	(37)
35    <sub>c</sub>	5.4		10.2	41.4	48.7	21.9	28.5	27.7	26.2		23.9	(37)
36    <sub>o</sub>	1.5		18.9	48.0	62.0	42.5	25.5	22.1	20.3		19.1	(39)
36 ⊥ <sub>o</sub>	2.4		24.9	50.5	39.0	28.2	23.5	22.1	20.5		19.3	(39)
37    <sub>o</sub>	6.0		5.7	6.4	41.2	55.5	36.4	45.5	34.3		25.2	(37)
37    <sub>b</sub>	6.9		5.7	5.9	40.9	56.5	13.4	33.0	52.2		43.3	(37)
37    <sub>c</sub>	6.3		8.2	22.2	68.1	37.5	24.2	17.4	29.4		26.7	(37)
38    <sub>o</sub>	2.1		12.9	40.4	86.0	78.9	37.7	26.1	24.4		21.1	(38)
38 ⊥ <sub>o</sub>	4.5		15.0	52.1	66.5	38.1	28.4	25.2	24.6		21.6	(38)
41    <sub>o</sub>	7.1	0.6	6.6	21.0	22.2	11.1	4.1	2.9		36.7	38.0	(38)
41 ⊥ <sub>o</sub>	3.5	2.4	8.7	26.5	29.9	18.1	11.7	8.5		20.9	19.1	(38)
43    <sub>o</sub>	33.7		17.2		16.2	15.8	17.7			18.1	18.1	(38)
43 ⊥ <sub>o</sub>	33.9		24.2		22.6	21.3	22.0			22.2	21.1	(38)
43††	29.2		14.4	19.9	17.3	15.2	16.8	19.0		18.3	17.8	(37)
43†† ⊥	32.3		22.1	24.2	23.1	17.1	22.1	21.5		21.3	20.0	(37)

† For  $\lambda = 24\mu$ .\*\* At 0°C,  $R_{117\mu} = 11.8$ ,  $R_{310\mu} = 14.9$ ; at 30°C,  $R_{117\mu} = 13.2$ ,  $R_{310\mu} = 17.1$ .†† For  $\lambda = 110$ .

‡‡ Red tourmaline.



TABLE 2.—WAVE-LENGTHS ( $\lambda_m$ ) OF MAXIMA OF SPECULAR REFLECTIVITY

Incident light unpolarized except for  $\text{ZnSeO}_4$  to  $\text{NiK}_2(\text{SeO}_4)_2$ , where data are marked thus:  $\parallel_a, \parallel_b, \parallel_c, [\perp_a]$  = plane of electric vector is parallel to optic axis, to  $a, b, c$  crystallographic axis, [perpendicular to optic axis].

*Additional Data.*— $\lambda_m$  for Nd-compounds, visible (34); effect of water of crystallization on  $\lambda_m$  in infra-red, alums, sulfates, selenates (9, 77); aqueous solutions of salts of strong acids (5). Unit of  $\lambda_m = 1\mu = 10^{-4}\text{\AA} = 10^{-4}\text{ cm}$ . See also Tables 1 and 3.

Substance	$\lambda_m$		
(80)			
AgClO <sub>3</sub> .....	10.76	16.38	
Ba(ClO <sub>3</sub> ) <sub>2</sub> .....	10.24		19.6
KClO <sub>3</sub> .....	10.12	16.22	
NaClO <sub>3</sub> .....	10.04	16.04	
(80)			
AgBrO <sub>3</sub> .....		12.6	13.1
Ba(BrO <sub>3</sub> ) <sub>2</sub> .....	12.3	12.64	
Cd(BrO <sub>3</sub> ) <sub>2</sub> .....	12.3		13.2
NaBrO <sub>3</sub> .....	12.2		
(12, 31, 54, 61, 76)			
H <sub>2</sub> SO <sub>4</sub> .....	7.2	8.6	10.4
H <sub>2</sub> SO <sub>4</sub> *.....	8.6	9.6	11.35
BaSO <sub>4</sub> .....	8.9		15.8
BeSO <sub>4</sub> .....	8.82	9.08	16.04
CaSO <sub>4</sub> .....	8.68		14.84
CdSO <sub>4</sub> .....		9.05	15.96
CoSO <sub>4</sub> .....		9.05	
CuSO <sub>4</sub> .....		9.15	15.88
FeSO <sub>4</sub> .....		9.1	
Fe <sub>2</sub> (SO <sub>4</sub> ) <sub>3</sub> .....		9.05	
K <sub>2</sub> SO <sub>4</sub> .....	8.83		15.92
Li <sub>2</sub> SO <sub>4</sub> .....	8.76		15.32
MgSO <sub>4</sub> .....	8.70	9.25	
Na <sub>2</sub> SO <sub>4</sub> .....	8.72†	9.02	16.08†
NiSO <sub>4</sub> .....		9.04	15.74
SrSO <sub>4</sub> .....	8.4	9.1	15.75
ZnSO <sub>4</sub> .....		9.2	
M(NH <sub>4</sub> ) <sub>2</sub> (SO <sub>4</sub> ) <sub>2</sub> †.....		9	16
MK <sub>2</sub> (SO <sub>4</sub> ) <sub>2</sub> †.....		9	16
K, Alum§.....		9.04	16.74
(57)			
KHSO <sub>3</sub> .....	8.21		
(79)			
CdSeO <sub>4</sub> .....	11.44		
CuSeO <sub>4</sub> .....	11.52		
K <sub>2</sub> SeO <sub>4</sub> .....	11.20		
Mn <sub>2</sub> (SeO <sub>4</sub> ) <sub>3</sub> .....	11.36		
NiSeO <sub>4</sub> .....	11.44		
ZnSeO <sub>4</sub> .....	11.44	<sub>a</sub> 11.43	⊥ <sub>a</sub> 11.48
LiNaSeO <sub>4</sub> .....		11.42	11.30
	<sub>a</sub>	<sub>b</sub>	<sub>c</sub>
Co(NH <sub>4</sub> ) <sub>2</sub> (SeO <sub>4</sub> ) <sub>2</sub> .....	11.56	11.22	11.12
Ni(NH <sub>4</sub> ) <sub>2</sub> (SeO <sub>4</sub> ) <sub>2</sub> .....	11.42	11.30	11.15
NiK <sub>2</sub> (SeO <sub>4</sub> ) <sub>2</sub> .....	11.32	11.56	11.18
(12, 54, 78)			
HNO <sub>3</sub> .....	7.85	10.55	
AgNO <sub>3</sub> .....	7.45		
Ba(NO <sub>3</sub> ) <sub>2</sub> .....	7.3	13.7	15.6
HgNO <sub>3</sub> .....	8.06	12.5	15.9
	10.08		
KNO <sub>3</sub> .....	7.13		
NaNO <sub>3</sub> .....	7.12	12.04	14.44

Substance	$\lambda_m$		
(12, 54, 78)			
$\text{Pb}(\text{NO}_3)_2$	7.72	13.9	15.9
$\text{Rb}(\text{NO}_3)$	7.24	12.3	15.2
$\text{Sr}(\text{NO}_3)_2$	7.28	12.36	15.36
Substance	$\lambda_m$		
(12, 35)			
$\text{AlPO}_4$	9.25	9.7	
$\text{BiPO}_4$	9.2 to 10.0	10.9	16.6 to 18.15
$\text{Ca}_3(\text{PO}_4)_2$	9.5		
$\text{Li}_3\text{PO}_4$	9.25		16.4 to 19.1
$\text{Mg}_3(\text{PO}_4)_2$	9.4	10.5	17.1
$\text{Na}_3\text{PO}_4$	9.6		17.5 to 18.0
$\text{Pb}_3(\text{PO}_4)_2$		10.15	17.25 to 18.7
$\text{Sr}_3(\text{PO}_4)_2$	8.7 to 9.8		
$\text{Zn}_3(\text{PO}_4)_2$	9.4		16.6
$\text{Na}_4\text{P}_2\text{O}_7$	7.9 to 9.15 to 11.16		19.0
Substance	$\lambda_m$		
(35)			
$\text{Ag}_4\text{P}_2\text{O}_7$	9.2 to 11.2	14.3 to 19.3	
$\text{K}_4\text{P}_2\text{O}_7$	7.75 to 9.05	11.2 to 14.8	18.7 to 19.15
$\text{Na}_4\text{P}_2\text{O}_7$	8.5 to 10.9	12.5 to 13.6	17.4 to 18.7
$\text{Pb}_2\text{P}_2\text{O}_7$	8.0 to 8.95	9.9 to 11.1	13.5
Substance	$\lambda_m$		
(12, 13, 45, 57, 76)			
$\text{BaCO}_3\parallel$	6.85	11.6	14.5
$\text{CaCO}_3\parallel$	6.7	11.4	14.2
$\text{Cu}_2(\text{CO}_3)_2(\text{OH})_2^{**}$	7.0	11.92	14.16
		10.54	
$(\text{CuOH})_2\text{CO}_3\uparrow\uparrow$	7.2	11.56	13.32
	6.65	9.64	12.14
$\text{CaMg}(\text{CO}_3)_2\uparrow\uparrow$	6.9	11.5	14.7
$\text{FeCO}_3\S\S\S$	6.8	11.5	13.7
$\text{MgCO}_3\parallel\parallel$	6.62	11.32	
$\text{MnCO}_3\parallel\parallel$	6.7	11.42	14.0
$\text{Na}_2\text{CO}_3$	7.0	11.48	14.56
$\text{PbCO}_3^{***}$	7.1	11.97	15.0
$\text{SrCO}_3\uparrow\uparrow\uparrow$	6.74	11.6	14.32
$\text{ZnCO}_3\uparrow\uparrow\uparrow$	6.76	11.4	13.71
Substance	$\lambda_m$		
(11, 57, 79)			
$\text{Ag}_2\text{CrO}_4$	11.45 to 11.95		
$\text{Ag}_2\text{Cr}_2\text{O}_7$	10.78 to 11.15	11.54 to 11.88	14.05
$\text{BaCrO}_4$	11.08	11.58	
$\text{CaCrO}_4$	10.96		
$\text{K}_2\text{CrO}_4$	10.88 to 11.10		
$\text{K}_2\text{Cr}_2\text{O}_7$	10.35		12.5
$\text{Li}_2\text{CrO}_4$	10.75		
$\text{MgCrO}_4$	10.90		
$\text{PbCrO}_4$		11.45 to 11.65 to 12.10	
$\text{SrCrO}_4$		10.65 to 11.35 to 11.80	
$\text{C}_2\text{H}_3\text{O}_3\S\S\S$	4.8	9.7 (54)	
* $\text{H}_2\text{SO}_4 + x\text{H}_2\text{O}$ .			
† Thenardite.			
‡ M = Co, Cu, Mg, Mn, Ni, or Zn.			
§ $\text{Al}_2(\text{SO}_4)_3 \cdot \text{K}_2\text{SO}_4 \cdot 24\text{H}_2\text{O}$ ; nearly same $\lambda_m$ for other alums.			
Witherite.			
¶ Same $\lambda_m$ for calcite, marble, and aragonite.			
** Azurite.			
†† Malachite.			
‡‡ Dolomite.			
§§ Siderite.			
Magnesite.			
¶¶ Rhodochrosite.			
*** Cerussite.			
††† Strontianite.			
‡‡‡ Smithsonite.			
§§§ Glycerol.			



TABLE 3.—WAVE-LENGTHS OF RESIDUAL RAYS

After many reflections from a given material the reflected radiation contains only a few ("residual") wave-lengths in the range  $18\mu$  to  $150\mu$ . Unit of  $\lambda = 1\mu = 10^4 \text{ \AA} = 10^{-4} \text{ cm}$ .

Substance	$\lambda$			$\lambda_{\text{mean}}$	Lit.
NH <sub>4</sub> Cl.....	46.3		54.0	51.5	(48, 75)
NH <sub>4</sub> Br.....	55.3		62.3	59.3	(75)
SiO <sub>2</sub> (see Vol. VI).....					
PbCl <sub>2</sub> .....	74	92	114	91	(68)
TiCl <sub>3</sub> .....		91.6			(75)
TiBr <sub>3</sub> .....		117			(75)
TiI <sub>3</sub> .....		151.8			(75)
HgCl <sub>2</sub> .....		95			(68)
Hg <sub>2</sub> Cl <sub>2</sub> .....	91.6		117.8	98.8	(68)
AgCl.....	74		90	81.5	(68)
AgBr.....		112.7			(68)
AgCN.....		93			(75)
MgCO <sub>3</sub> *.....		30.2			(13)
CaF <sub>2</sub> †.....	24.0	31.6			(66, 74)
CaF <sub>2</sub> ††.....	22.0	33.0			(19)
CaCO <sub>3</sub> §.....		29.4			(6)
CaCO <sub>3</sub>   .....	93		116	98.7	(67, 68)
CaCO <sub>3</sub> ¶.....		39			(37)
SrCO <sub>3</sub> **.....	43.2				(48)
BaCO <sub>3</sub> ††.....		46			(48)
NaCl†††.....	47		54	52	(48, 68, 70, 71)
NaCl††††.....		52			(19)
NaBr.....	50 to 55				(6)
KCl§§.....	62.3		70.6	63.4	(68, 70, 71)
KCl††§§.....		63			(19)
KBr.....	74.0		86.0	83.3	(6, 68, 71)
KBr†.....		83			(19)
KI.....		96			(68, 71)
KI†.....		94			(19)
H <sub>2</sub> KAl <sub>2</sub> (SiO <sub>4</sub> ) <sub>2</sub>    .....	18.4		21.5		(13, 74)

\* Magnesite.

† Fluorite.

†† Using only one reflecting surface and plane polarized light incident at the polarizing angle.

§ Marble.

|| Calcite.

¶ Aragonite.

\*\* Strontianite.

†† Witherite.

†† Rook salt.

§§ Sylvite.

||| Muscovite (mica).

TABLE 4.—POLARIZATION OF LIGHT BY REFLECTION FROM LIQUIDS

When unpolarized light is reflected at the boundary of two substances it is partially polarized; if for the reflected light  $I_{\parallel}$  [ $I_{\perp}$ ] = amplitude of component of the electric vector parallel [perpendicular] to the plane of incidence,  $I_{\perp} > I_{\parallel}$ . The angle at which  $(I_{\parallel}/I_{\perp})$  is a minimum is called Brewsterian angle; at that angle  $(I_{\parallel}/I_{\perp}) = k \times 10^{-2}$ . Data apply to clean surfaces.

Substance (60)	k
H <sub>2</sub> O, Water.....	75*
CCl <sub>4</sub> , Carbon tetrachloride.....	84
CS <sub>2</sub> , Carbon disulfide.....	142
CH <sub>3</sub> O, Methyl alcohol.....	69
C <sub>2</sub> H <sub>5</sub> O, Ethyl alcohol.....	66
C <sub>3</sub> H <sub>7</sub> O, Allyl alcohol.....	110
C <sub>4</sub> H <sub>9</sub> O, Acetone.....	81
C <sub>3</sub> H <sub>7</sub> O, n-Propyl alcohol.....	96
C <sub>3</sub> H <sub>7</sub> O, Isopropyl alcohol.....	110
C <sub>3</sub> H <sub>5</sub> O <sub>2</sub> , Glycerol.....	0
C <sub>4</sub> H <sub>9</sub> O, n-Butyl alcohol.....	92
C <sub>4</sub> H <sub>9</sub> O, Isobutyl alcohol.....	87

Substance (60)	k
C <sub>5</sub> H <sub>12</sub> , n-Pentane.....	170
C <sub>5</sub> H <sub>12</sub> O, Amyl alcohol.....	150
C <sub>6</sub> H <sub>5</sub> NO <sub>2</sub> , Nitrobenzene.....	131
C <sub>6</sub> H <sub>6</sub> , Benzene.....	107
C <sub>7</sub> H <sub>8</sub> , Toluene.....	194
C <sub>8</sub> H <sub>10</sub> , m-Xylene.....	202
C <sub>8</sub> H <sub>18</sub> , Octane.....	66
C <sub>16</sub> H <sub>32</sub> O <sub>2</sub> , Palmitic acid.....	190
C <sub>18</sub> H <sub>34</sub> O <sub>2</sub> , Oleic acid.....	210
Olive oil.....	107

\* Rayleigh (62) gives for H<sub>2</sub>O, k = 42.

**Diffusion Diagrams.**—When light is diffusely reflected, the intensity ( $I_{\theta}$ ) of the light reflected at the angle  $\theta$  depends upon the intensity ( $I_i$ ) of the incident light and also upon the angle ( $i$ ) of incidence, and varies with  $\theta$ . The distribution of the reflected light when the surface is illuminated by a beam of parallel light may be shown by a diffusion diagram (Figs. 1 to 4) in which the value of ( $I_{\theta}$ ) for any value of  $\theta$  is represented by a point at a distance equal to ( $I_{\theta}$ ) from a common center and in the direction  $\theta$ . If  $I_{\theta} = I_{\theta 0} \cos \theta$ , these points will lie upon a circle tangent to the surface. Data additional to Figs. 1 to 4: Diffusion by non-metals (1, 7, 23, 24, 43, 90), by roughened metals (44); polarization and depolarization by diffuse reflection (10, 46).

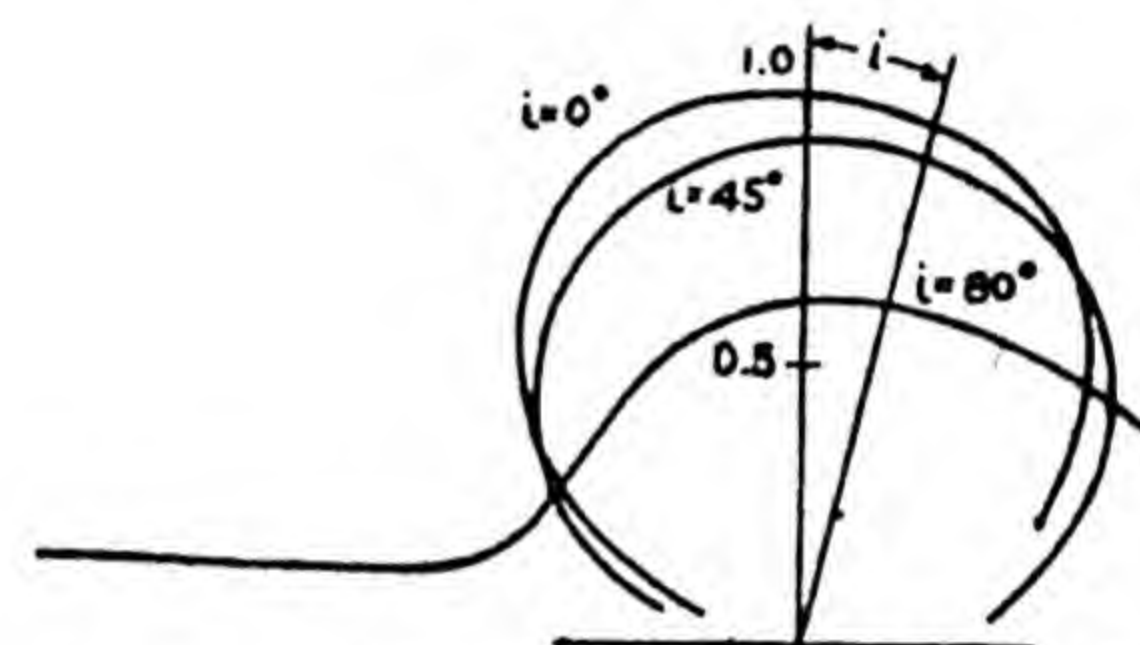


FIG. 1.—Diffusion diagram: MgO (60).

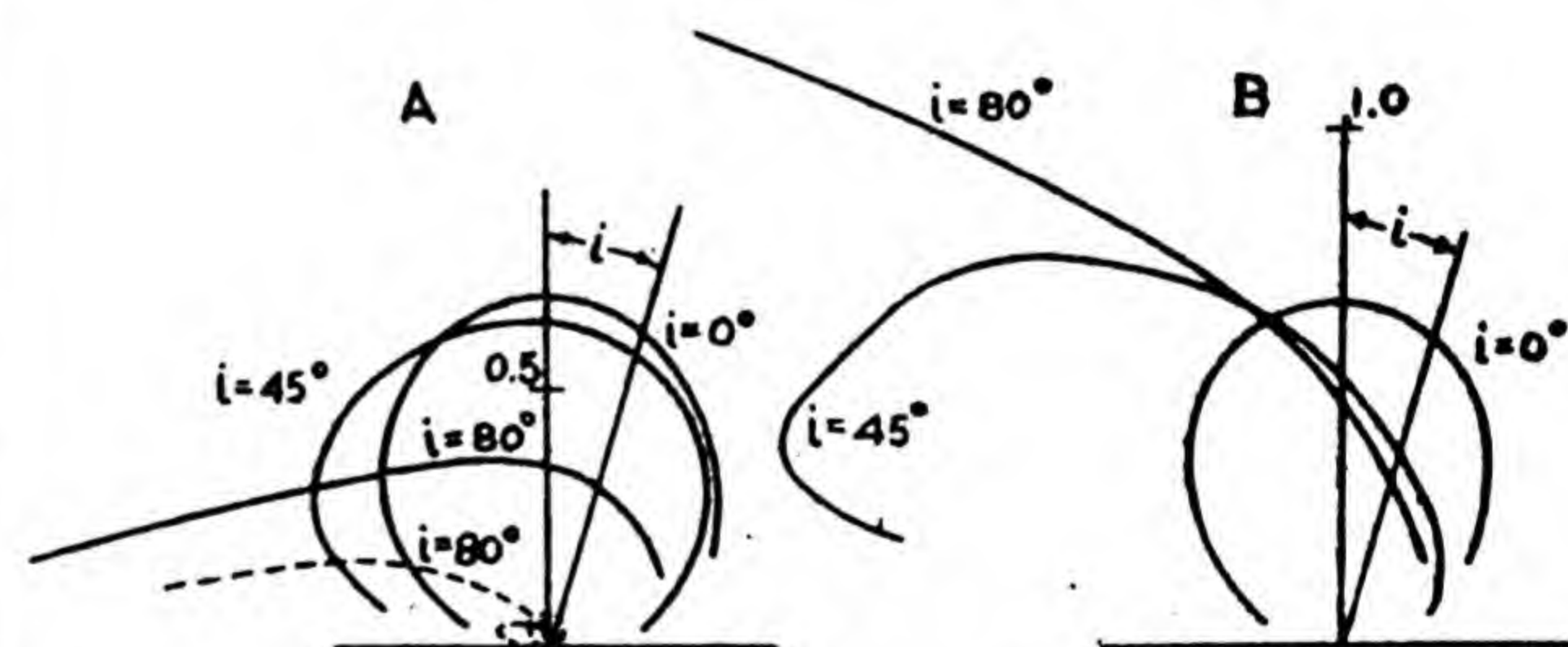
 $\lambda = 0.55\mu$ ; unit intensity =  $(I_{\theta 0})_{i=0}$ .

FIG. 2.—Diffusion diagram: Rhodamine B on white drawing paper (60).

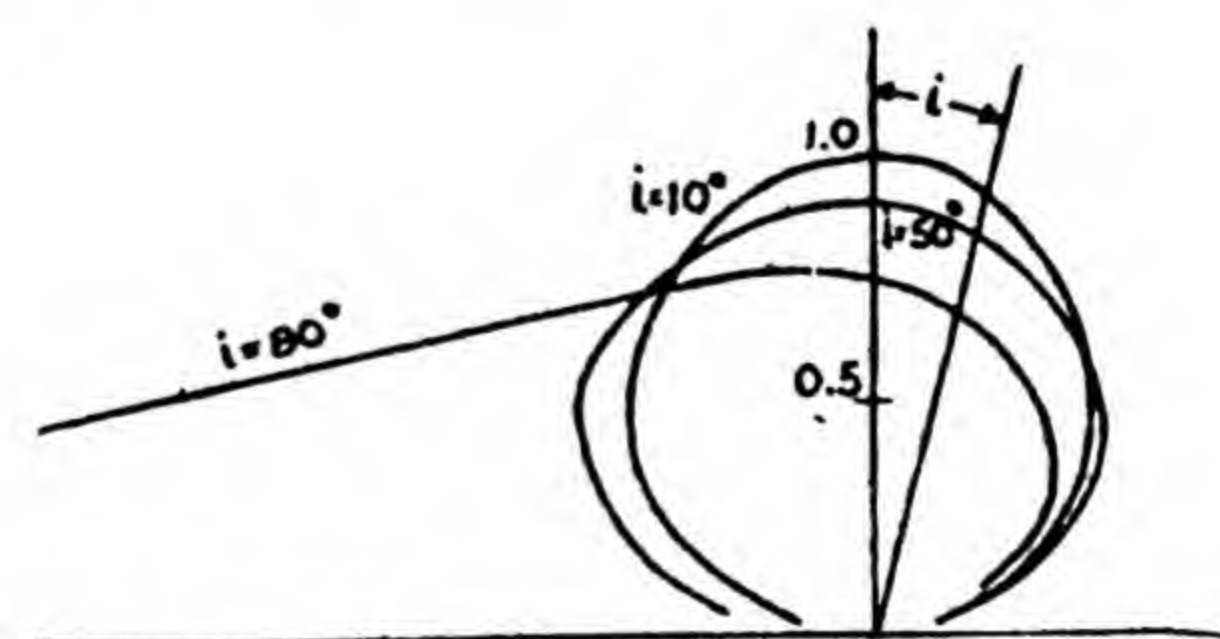
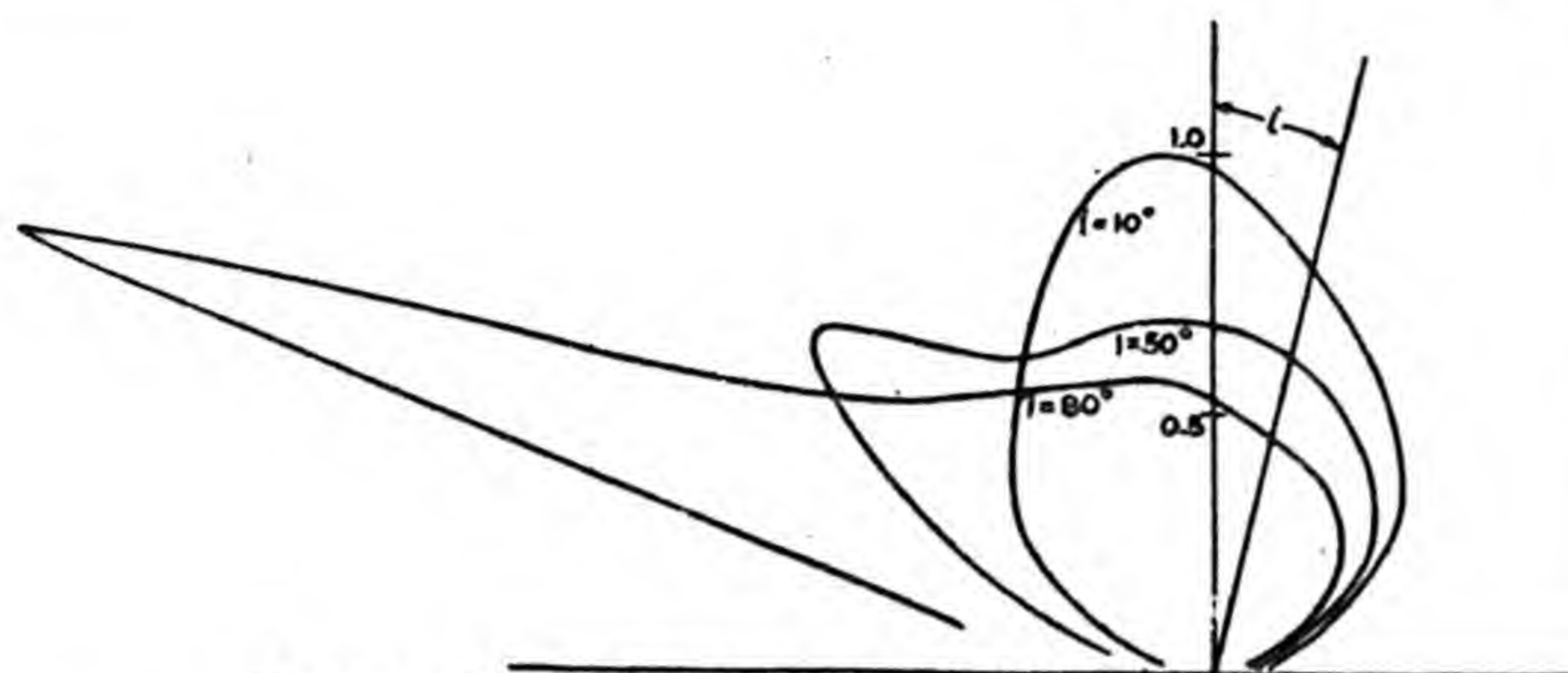
Unit intensity =  $(I_{\theta 0})_{i=0}$  for MgO. In A, —  $\lambda = 0.65\mu$ , - - -  $\lambda = 0.55\mu$ ; in B,  $\lambda = 0.55\mu$ .

FIG. 3.—Diffusion diagram: Roughened milk glass (60).

White light, glass roughened with emery paper; unit intensity =  $(I_{\theta 0})_{i=0}$ .



FIG. 4.—Diffusion diagram:  $\text{CaSO}_4$  plaque (85).

White light; plaster of Paris ( $\text{CaSO}_4$ ) cast on a glass surface, reflection from the smooth surface; unit intensity =  $(I_{ro})_{i=0}$ .

TABLE 5.—ALBEDO: WHITE LIGHT

$A$  = Albedo =  $F_r/F$ ;  $F_r$  = total luminous flux (in complete hemisphere) reflected from a plain surface coated with the material and uniformly illuminated with white light, the total luminous flux incident upon it being  $F$ . Pg = ground pigment; Pt = applied and dried paint; w Pg = white pigment. Paints and pigments are arranged in the order: Black, white, gray, red, yellow, green, blue, purple. Same system of key numbers ( $N$ ) for Tables 5 and 6. Unit of  $A$  = 0.01 = 1%.

$N$	Substance		$A$	Lit.
2	$\text{H}_2\text{O}$ , snow		93*	(51)
3	$\text{H}_3\text{BO}_3$		94*	(51)
4	$\text{Al}_2\text{O}_3$		94*	(51)
9	$\text{MgO}$		97*	(26, 51, 55)
11	$\text{HSbO}_3$	w Pg	89	(21)
13	$\text{ZnO}$	w Pg	91	(21)
14	$\text{CaCO}_3$		95*	(51)
15	$\text{MgCO}_3$		98	(30, 55, 84)
17	$\text{BaSO}_4$	w Pg	88	(21)
18	Munsell cards:			
	Gray	N9	74	(59)
		N7	47	(59)
		N5	24	(59)
		N3	9	(59)
		N1	2	(59)
	Red	r $\frac{7}{8}$	46	(59)
		r $\frac{5}{8}$	22	(59)
		r $\frac{3}{8}$	9	(59)
	Yellow	y $\frac{7}{4}$	50	(59)
		y $\frac{5}{8}$	28	(59)
		y $\frac{3}{8}$	10	(59)
	Green	g $\frac{7}{4}$	49	(59)
		g $\frac{5}{8}$	25	(59)
		g $\frac{3}{8}$	9	(59)
	Blue	b $\frac{7}{4}$	49	(59)
		b $\frac{5}{8}$	26	(59)
		b $\frac{3}{8}$	9	(59)
	Purple	p $\frac{7}{8}$	51	(59)
		p $\frac{5}{8}$	25	(59)
		p $\frac{3}{8}$	9	(59)
21	China clay†	Pg	84	(21)
22	Flat white x	Pt	71	(21)
23	Gloss white X	Pt	65	(21)
24	Lithopone	Pg	91	(21)
26	Titanium oxide	Pg	91	(21)
28	White lead†	Pg	90	(21)
31	Gray, light	Pt	49	(21)
32	Gray, medium	Pt	30	(21)
33	Pink, light	Pt	67	(21)
34	$F_1$ , red-brown§	Pt	6.37	(58)
	$F_2$ , red-brown§	Pt	6.46	(58)

$N$	Substance		$A$	Lit.
35	Red	Pt	13	(21)
36	Venetian red	Pg	11	(41)
37	Vermilion (Amer.)	Pg	14	(41)
38	Burnt sienna	Pg	11	(41)
39	Chrome yellow	Pg	55	(41)
40	Yellow, light	Pt	65	(21)
41	Cream, light	Pt	74	(21)
42	Chrome green	Pg	20	(41)
43	$A_1$ , green§	Pt	32.0	(58)
	$A_2$ , green§	Pt	32.4	(58)
44	Green, dark	Pt	12	(21)
45	Green, light	Pt	47	(21)
46	Cobalt blue	Pg	7	(41)
47	$C_1$ , blue§	Pt	19.6	(58)
	$C_2$ , blue§	Pt	19.1	(58)
48	Blue, light	Pt	61	(21)
49	Blue, medium	Pt	36	(21)
50	$B_1$ , red-purple§	Pt	24.8	(58)
	$B_2$ , red-purple§	Pt	24.6	(58)
	Airship fabric (Al coated)		33	(20)
	Airship fabric (black r.)		6	(20)
	Black velvet		ca. 1	(14, 83)
	Brown soil		32	(28)
	Green leaves		ca. 25	(2, 14, 28)
	Ink (various kinds)		1 to 4	(50)
	Paper, white		70 to 80	(2, 28, 55, 83)
	Print		60	(50)
	Science abstracts		62	(50)
	Azo¶ A (matt)		72	(50)
	Azo¶ C (glossy)		74	(50)
	Plaster (raw)		45	(50)
	Plaster (finished)		65	(50)
	Cement and lampblack, see (84)			

\* Value corrected to agree with  $A = 98\%$  for  $\text{MgCO}_3$ .

† Kaolin.

‡ Basic carbonate.

§ Camouflage paint.

|| Coated with black rubber.

¶ Photographic paper.

TABLE 6.—MONOCHROMATIC ALBEDO

$A_\lambda$  = Monochromatic albedo =  $F_{\lambda r}/F_\lambda$ ;  $F_{\lambda r}$  = total flux (in complete hemisphere) of radiant energy of wave-length  $\lambda$  reflected from a plain surface coated with the material and uniformly illuminated with radiation of wave-length  $\lambda$ , the total radiant flux of this  $\lambda$  incident upon it being  $F_\lambda$ . Normal incidence: Pg = powdered pigment; Pt = applied paint; b = black, gn = green, gy = gray, w = white, y = yellow. Same system of key numbers ( $N$ ) for Tables 5 and 6. Additional data: Flowers (64), paints (25), pigments (ultra-violet) (17). Unit of  $A_\lambda$  = 0.01 = 1%; of  $\lambda$  =  $1\mu = 10^4\text{\AA} = 10^{-4}\text{ cm}$ .

$\lambda$		0.2536	0.3131	0.3655	0.4047	0.4358
$N$	Material	$A_\lambda$ (56)				
1	S			7	8	18
13	$\text{ZnO}$	Pg		2	70	93
24	Lithopone	Pg	5	70	77	95
25	Timonox	Pg	5	35	60	85
27	Titanox	Pg	5	30	80	87
28	White lead*	Pg	5	60	75	75
29	White lead†	Pg	5	17	17	70

\* Basic carbonate.

† Sublimed.



$\lambda$		0.44	0.46	0.50	0.52	0.54	0.56	0.58	0.60	0.62	0.64	0.66	0.68	0.70	0.74
N	Material	$A_\lambda$ (40, 58)													
9	MgO†.....	Pg	8	6	5	6	6	9	11	24	39	53	61	66	65
37	Vermilion (Amer.)§.....	Pg	4	4	4	5	6	9	14	18	20	21	23	24	25
38	Burnt sienna§.....	Pg	5	5	8	18	48	66	75	78	79	81	81	81	81
39	Chrome yellow§.....	Pg													
43	A <sub>1</sub> , green  .....	Pt		23	28	33	37	36	34	28	24	21	18	16	15
	A <sub>2</sub> , green  .....	Pt		22	38	45	36	31	27	27	27	28	39	54	67
50	B <sub>1</sub> , red-purple  .....	Pt		27	22	21	21	22	26	32	32	29	27	24	23
	B <sub>2</sub> , red-purple  .....	Pt		28	23	22	23	22	24	28	31	33	43	58	70
47	C <sub>1</sub> , blue  .....	Pt		36	29	25	22	19	16	14	13	12	10	9	9
	C <sub>2</sub> , blue  .....	Pt		37	39	28	18	15	13	13	13	14	22	37	55
34	F <sub>1</sub> , red-brown  .....	Pt		4	4	5	5	5	7	9	11	10	11	10	10
	F <sub>2</sub> , red-brown  .....	Pt		5	7	5	5	6	6	8	8	9	14	26	42

† Effect of thickness ( $t$ ) of MgO applied to colorimeter plate; kind of plate is not stated (§§):

$t$	0.1	0.35	0.6 mm
100 $A_{red}/A_{green}$ .....	99.3	100.0	100.3
100 $A_{blue}/A_{green}$ .....	101.5	100.0	99.3

§ From Sherwin Williams Paint Co.

|| Camouflage paint (§§).

$\lambda$		0.6	0.95	4.4	8.8	24
N	Material	$A_\lambda$ (14)				
5	CaO.....	w Pg	85	22	4	6
6	Co <sub>2</sub> O <sub>3</sub> .....	gv Pg	3 4	14	13	6
7	Cr <sub>2</sub> O <sub>3</sub> .....	gn Pg	27 45	33	5	8
8	CuO.....	b Pg	24	15		4
9	MgO.....	w Pg	86	16	3	9
10	PbO.....	Pg	52	51	26	10
12	ThO <sub>2</sub> .....	Pg	86	47	7	10
13	ZnO.....	y Pg	82 86	9	3	5
13	Zinc oxide No. 104¶.....	Pt	68 72			
15	MgCO <sub>3</sub> .....	w Pg	85 89	11	4	9
19	Lampblack.....	Pt	3 3.4	3.5	3.8	4.4
19	Lampblack (various flames)		1.0	1.0	1.5	4
20	Platinum black, paint.....	Pt	2 2.7	5.9	8.7	12.1
	Electrolytic, 1 min.**.....		1	1.5	25	
	Electrolytic, 2 to 3 min.**.....		1	1.5	11	7.5
	Electrolytic, 3 min.** (§§).....		1.5	6	7	
	Electrolytic, 4 to 6 min.**.....		1	1.5	2	4
28	White lead No. 103¶.....	Pt	76 79			
30	Zinc lead white No. 107¶.....	Pt	70			

¶ In linseed oil; Sherwin Williams Paint Co.'s number.

\*\* Electrolytically deposited on Pt (14) [on Ag (§§)] for time indicated

## LITERATURE

(For a key to the periodicals see end of volume)

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- (10) Chimyrow and Slatowiatsky, *63*, 7: 533; 06. (11) Clark, *21*, 35: 48; 12. (12) Coblenz, *152*, No. 65: 06. (13) Coblenz, *152*, No. 97: 08. (14) Coblenz, *31A*, 9: 283; 13. (15) Coblenz and Hughes, *31A*, 19: 577; 24. (16) Coblenz and Kahler, *31A*, 15: 121; 18. (17) Cochrane, *68*, 35: 146; 14. (18) Crandall, *2*, 2: 343; 13. (19) Czerny, *96*, 16: 321; 23. (20) Edwards and Long, *32*, No. 128; 19. (21) Gardner, *84*, 17: 318; 22. (22) Gehrts, *8*, 47: 1059; 15. (23) Gilpin, *84*, 5: 854; 10. (24) Gorton, *2*, 7: 66; 16. (25) Hallett, *66*, 23 II: 279; 23. (26) Henning and Heuse, *96*, 10: 111; 22. (27) Hulburt, *21*, 46: 1; 17. (28) Hutchins, *12*, 6: 373; 98. (29) Johnson and Spence, *2*, 5: 349; 15. (30) Karrer, *48*, 5: 96; 21. (31) Koch, *8*, 26: 974; 08. (32) Koenigsberger, *8*, 43: 1205; 14. (33) Koenigsberger and Reichenheim, *189*, 1905: 454. (34) Koller, *Thesis*, Freiburg, 1914. *10*, 4: 537; 21. (35) Langford, *2*, 23: 137; 11. (36) Lewis and Hardy, *2*, 14: 272; 19. (37) Liebisch and Rubens, *76*, 1919: 198. (38) Liebisch and Rubens, *76*, 1919: 876. (39) Liebisch and Rubens, *76*, 1921: 211. (40) Luckiesh, *143*, 184: 73; 17. (41) Luckiesh, *84*, 17: 315; 22. (42) Martens, *8*, 6: 603; 01. (43) Messerschmidt, *8*, 34: 867; 88. (44) Meyer, *88*, 16: 126; 14. (45) Morse, *21*, 26: 225; 07. (46) Návrát, *76*, 120 IIa: 1229; 11. (47) Nichols, *76*, 1896: 1183. (48) Nichols and Day, *2*, 27: 225; 08. (49) Nutting, *2*, 13: 193; 01. (50) Nutting, *84*, 10: 379; 15. (51) Nutting, Jones and Elliott, *84*, 9: 593; 14. (52) Nyswander, *2*, 28: 291; 09. (53) Peter, *96*, 15: 358; 23. (54) Pfund, *21*, 24: 19; 06. (55) Pfund, *143*, 189: 371; 20. (56) Pfund, *66*, 23 II: 369; 23. (57) Porter, *21*, 22: 229; 05. (58) Priest, *48*, 4: 388; 20. (59) Priest, Gibson and McNicholas, *32*, No. 167; 20. (60) Raman, C. V., Calcutta, India, *0*. (61) Randall, *21*, 34: 308; 11. (62) Rayleigh, *Collected Works*, 3: 511; 02. (63) Reinkober, *8*, 34: 343; 11. (64) Richtmyer, *48*, 7: 151; 23. (65) Royds, *3*, 21: 166; 11. *63*, 11: 316; 10. (66) Rubens, *8*, 69: 576; 99. (67) Rubens, *88*, 13: 102; 11. (68) Rubens, *76*, 1913: 513. (69) Rubens, *88*, 17: 315; 15. (70) Rubens and Aschkinass, *8*, 65: 241; 98. (71) Rubens and Hollnagel, *88*, 12: 33; 10. *76*, 1910: 26. (72) Rubens and Ladenburg, *76*, 1908: 274, 1140. (73) Rubens and Ladenburg, *88*, 11: 16; 09. (74) Rubens and Nichols, *8*, 60: 418; 97. (75) Rubens and von Wartenberg, *76*, 1914: 169. (76) Schaefer and Schubert, *8*, 50: 283; 16. (77) Schaefer and Schubert, *8*, 50: 339; 16. (78) Schaefer and Schubert, *8*, 55: 577; 18. (79) Schaefer and Schubert, *96*, 7: 297; 21. (80) Schaefer and Schubert, *96*, 7: 309; 21. (81) Sieg, *48*, 7: 147; 23. (82) Sihvoren, *96*, 20: 272; 23. (83) Sumpner, *3*, 35: 81; 93. (84) Taylor, *31A*, 16: 421; 20. (85) Thaler, *8*, 11: 996; 03. (86) Trowbridge, *2*, 27: 282; 08. (87) Tyndall, *2*, 21: 162; 23. (88) Van Dyke, *48*, 6: 917; 22. (89) Woronkoff and Potrowski, *96*, 20: 358; 24. (90) Wright, *3*, 49: 199; 00. *8*, 1: 17; 00.



## TOTAL (NON-SPECTRAL) TRANSMISSION OF RADIATION

JOHN W. T. WALSH AND H. BUCKLEY

Data for the transmission of long electric waves, X-rays and gamma rays are excluded from this section; for the rest of the spectrum reliable quantitative data for the total transmission are available for only a very few substances. For spectral transmission, *v.* p. 268 and 359.

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## SYMBOLS

(*v.* also Vol. I, p. 16; others defined where used)

$I$  [ $I'$ ] Intensity of radiation incident upon [transmitted by] a given plate of material.  $I = \int_0^\infty I_\lambda d\lambda$ ;  $I' = \int_0^\infty I'_\lambda d\lambda$ .

$I_l$  [ $I'_l$ ] Luminous intensity of  $I$  [ $I'$ ].  $I_l = \int_0^\infty \Lambda_\lambda I_\lambda d\lambda$ .

$P$  Pressure.

$p$  % defect in polarization = 100  $w/s$ .

$S_t$  Intensity of light scattered by the substance at temperature  $t$ .

$S_a$  [ $S_{a,s}$ ] Intensity of light scattered by air at  $t = 0^\circ\text{C}$ ,  $P = 760$  mm of Hg [by liquid  $(\text{C}_2\text{H}_5)_2\text{O}$  at  $35^\circ\text{C}$ ].

$s$  [ $w$ ] Strongest [weakest] plane polarized component of the scattered light.

$t$  Temperature,  $^\circ\text{C}$ .

$w$  See  $s$ .

$\alpha$  Absorption factor =  $(I - I')/I = 1 - \tau$ ;  $\alpha_l = 1 - \tau_l$ .

Reflection losses taken as zero.

$\beta$  Angle observed light makes with incident beam.

$\theta$  [ $\varphi$ ] Angle of view [of incidence] measured from normal to surface.

$\Lambda_\lambda$  Visibility factor.  $I_l = \int_0^\infty \Lambda_\lambda I_\lambda d\lambda$ .

$\tau$  Transmission factor =  $I'/I$ ;  $\tau_l = I'_l/I_l$ , reflection losses being taken as zero.

TABLE 1.—TRANSMISSION FACTOR FOR RADIATION ( $\tau$ ) AND LIGHT ( $\tau_l$ ) FROM A BLACK-BODY

$T$  = temperature of the black-body ( $^\circ\text{K}$ );  $x$  = thickness of transmitting plate (mm)

Substance	$x$	$T$			$T$			Lit.
		2400	3600*	5000	2400†	3600*	5000‡	
$\text{H}_2\text{O}$ , Water.....	10	22.5	50	69	0.10	0.38	0.07	(1, 2, 14)
	100	9	31.5	54	1.04	0.84	0.74	(1, 2, 14)
$\text{SiO}_2$ , Quartz.....	10	90	98.5	99	Practically zero			(13)
	100	84	95	98	Practically zero			(13)
$\text{NaCl}$ , Rock salt.....		Very great			Practically zero			(13)
$\text{KCl}$ , Sylvite.....		Very great			Practically zero			(13)
$\text{CaF}_2$ , Fluorite.....		Very great			Practically zero			(13)
Glass, Crown§.....	10	85	91	97	1.35	1.38	1.40	
	100	65	74	80	12.5	12.6	12.7	
Glass, Light flint§.....	10	86	92	97	1.22	1.25	1.28	
	100	66	75	80	11.4	11.5	11.7	

\* Corresponds to plain carbon arc.

† Corresponds to W-filament vacuum lamp at 9 lumens per watt.

‡ White light; approximately noon sunlight.

§ Typical data.

## Color Filters for Photometry of Black-Body Sources

Suitable dilutions of stock solutions A and B may be used to produce a color match between two sources which, in the visible spectrum, radiate approximately like black-bodies (19).

Stock A, yellow: 100 g  $\text{CoSO}_4(\text{NH}_4)_2 \cdot 6\text{H}_2\text{O} + 0.733$  g  $\text{K}_2\text{Cr}_2\text{O}_7 + 10$  cm<sup>3</sup>  $\text{HNO}_3$  ( $d = 1.05$ ) +  $\text{H}_2\text{O}$  to make 1 l of solution. Stock B, blue: 50 g  $\text{NiSO}_4(\text{NH}_4)_2 \cdot 6\text{H}_2\text{O} + 10$  g  $(\text{NH}_2)_2\text{SO}_4 + 55$  cm<sup>3</sup>  $\text{NH}_4\text{OH}$  ( $d = 0.90$ ) +  $\text{H}_2\text{O}$  to make 1 l of solution. Stock A is to be diluted with  $\text{H}_2\text{O}$ ; stock B with a solution of 10 g  $(\text{NH}_4)_2\text{SO}_4$  in 1000 cm<sup>3</sup>  $\text{H}_2\text{O}$ . For transmission, *v.* Figs. 1A, 1A<sub>t</sub>, and 1B.

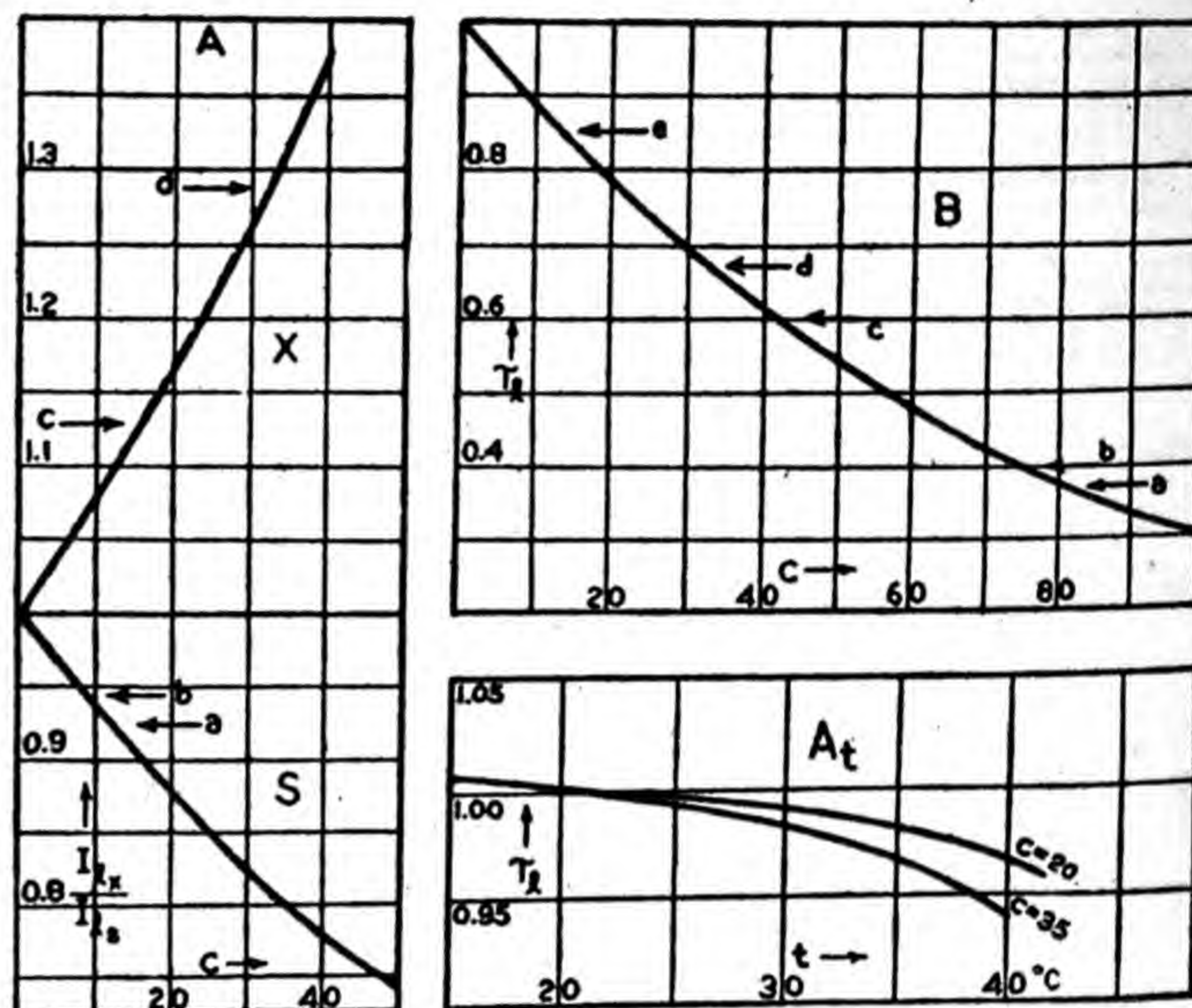


FIG. 1.—Factors for solutions A and B.

Source: Carbon filament lamp at 4 watts per candle. Solution is 1 cm thick. Unit of concentration ( $C$ ) = 1 cm<sup>3</sup> stock per 100 cm<sup>3</sup> of solution. C-1 [W-1] = carbon [tungsten] filament lamp; w. p. h. c. = watts per horizontal candle; w. p. m. s. c. = watts per mean spherical candle.

A. Multiplication factor for solution A at  $20^\circ\text{C}$ .  $I_{ls}$  [ $I_l$ ] = luminous intensity of source  $x$  [of standard C-1 at 4 w. p. c.]; in section S [X], filter is in front of standard [of source  $x$ ]. For S,  $\tau_l = I_{ls}/I_l$  and  $\log_{10} \tau_l = -0.245(0.01C)^{0.85}$ ; for X,  $\tau_l = I_{ls}/I_l$  and  $\log_{10} \tau_l = -0.366(0.01C)^{1.05}$ . Color match: a = Hefner lamp, b = Pentane lamp, c = W-1 at 1.25 w. p. h. c., d = W-1 at 0.65 w. p. m. s. c.

A<sub>t</sub>. Variation of transmission factor ( $\tau$ ) of solution A with temperature. Ordinates are  $(\tau_t)^{10}/(\tau)^{10}$ .

B. Transmission factor ( $\tau$ ) of solution B at  $20^\circ\text{C}$ .  $\tau_l$  is practically independent of temperature;  $\log_{10} \tau_l = -0.539(0.01C)^{1.05}$ . Color match: a = W-1 at 0.5 w. p. m. s. c., b = W-1 at 0.65 w. p. m. s. c., c = W-1 at 1.0 w. p. h. c., d = W-1 at 1.25 w. p. h. c., e = C-1 at 3.1 w. p. h. c.

## Diffusing Materials

On transmission through a plate of diffusing material, such as opal glass, light is scattered in all directions; the apparent brightness of the second surface depends on (a) the material, its thickness, and the state of its surface; (b) the angle of incidence of the light; (c) the angle of view, and the relation between the plane of incidence and that of the direction of view.

The first (a) is so dependent on small variations in manufacture that only typical data can be given (4, 21, 27); see Figs. 2, 3.



In general  $\log_{10} \tau_i = ax^b$ , where  $x$  is the thickness and  $a$  and  $b$  are constants of the material; for a certain opal glass (12)  $a = -0.282$  and  $b = 0.80$  if unit of  $x$  is 1 mm.

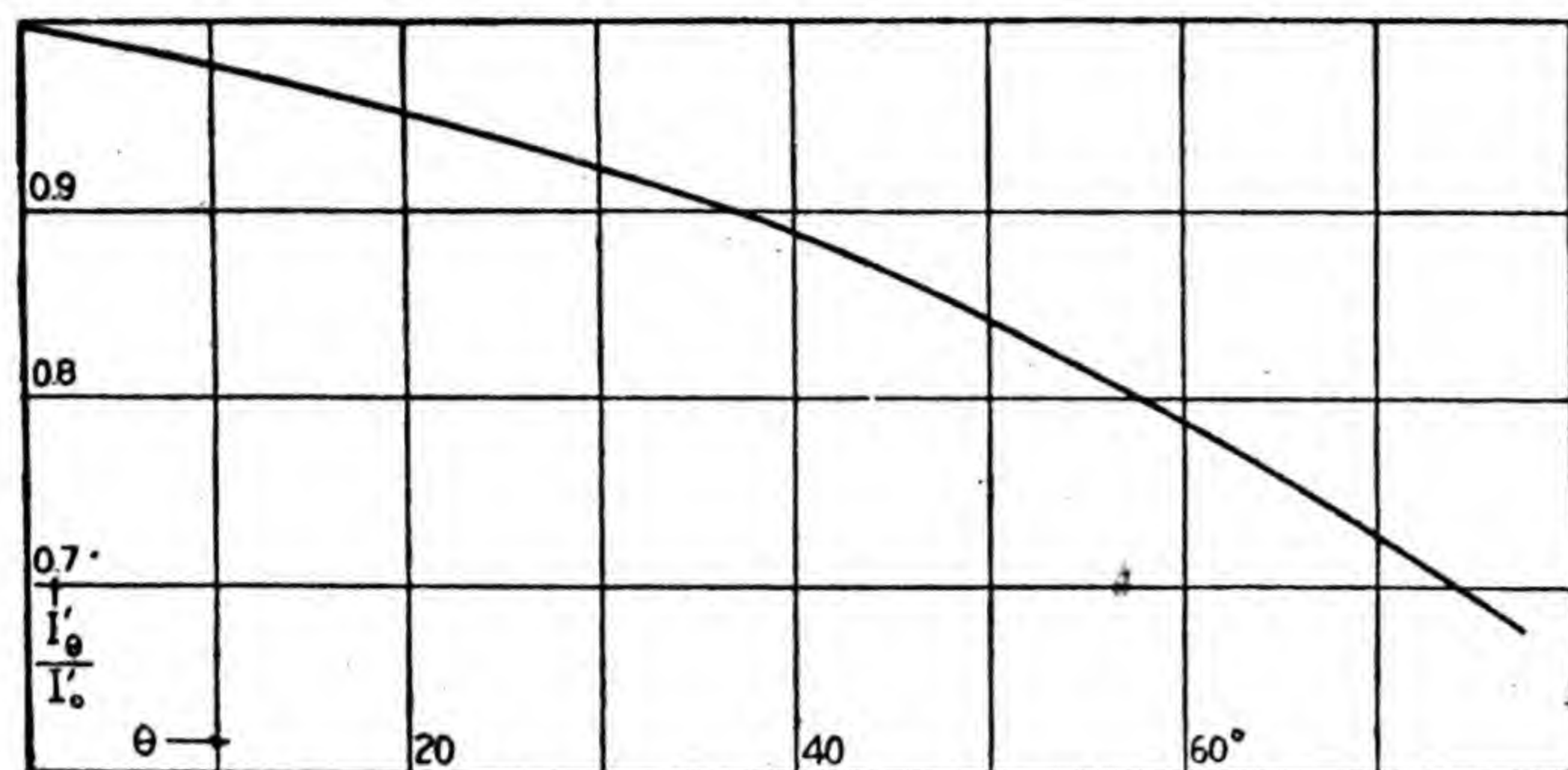


FIG. 2.—Diffuse transmission: Variation of brightness with angle ( $\theta$ ) of view (27).

Opal glass; incidence normal ( $\varphi = 0$ ).

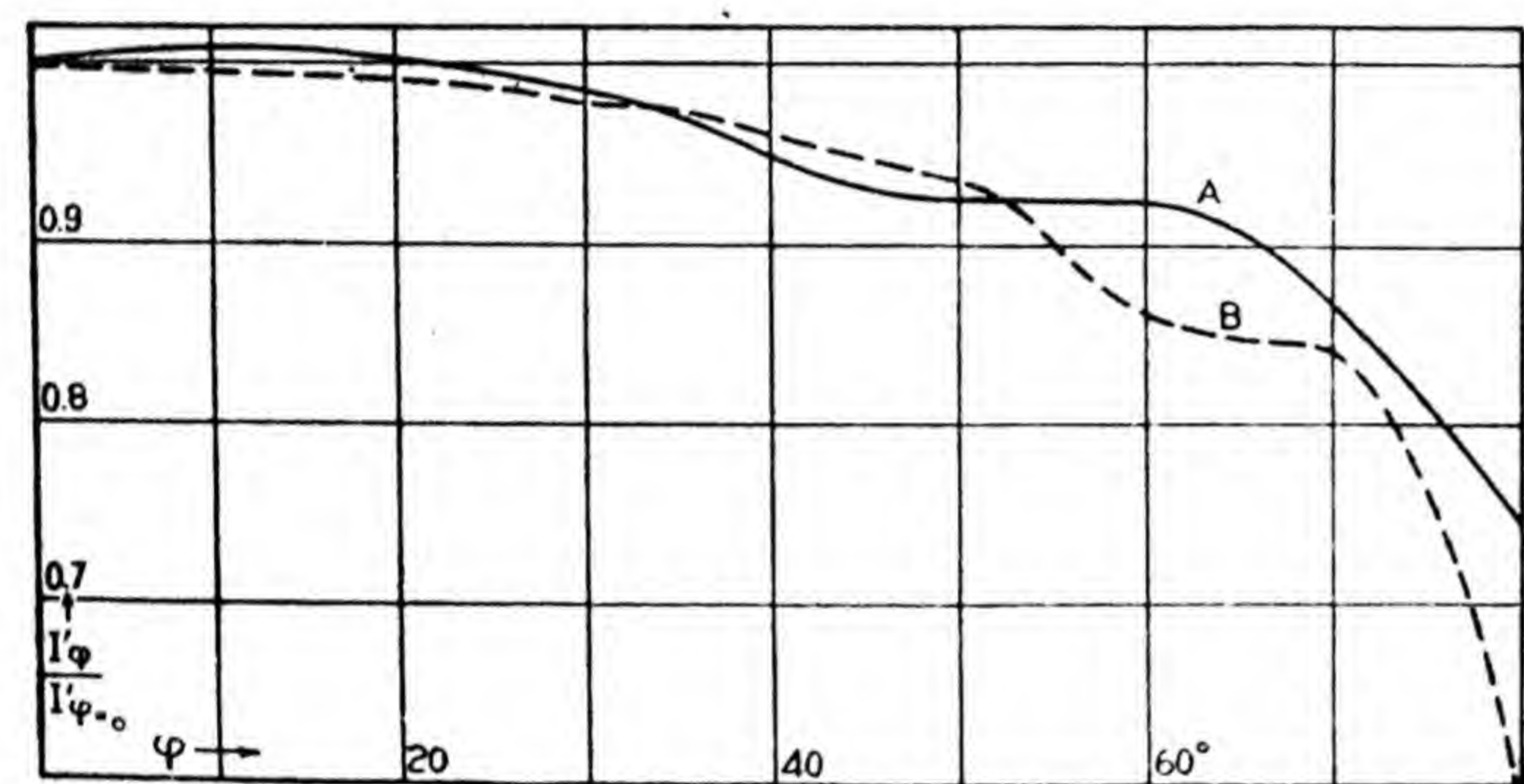


FIG. 3.—Diffuse transmission: Variation of brightness with angle ( $\varphi$ ) of incidence (29).

Opal glass; angle of view normal ( $\theta = 0$ ). Curve A is for rough (depolished) and B is for polished glass.

TABLE 2.—ABSOLUTE INTENSITY OF LIGHT SCATTERED Laterally BY DUST-FREE GASES AND LIQUIDS

$I_{\beta}/I_0$  = Luminous intensity of incident light [of light scattered at angle  $\beta$  to the incident beam];  $v$  = volume of the gas which participates in the scattering;  $V. P.$  = pressure of saturated vapor;  $t_c, P_c$  = critical temperature and pressure. If  $\beta = 90^\circ$ ,  $I_{\beta} = RvI_0$ .

Unit of  $R = 1 \text{ cm}^{-2}$ ; of  $P = 1 \text{ mm of Hg}$ ; of  $\lambda = 1 \text{ A} = 10^{-8} \text{ cm}$ ;  $t$  is  $^\circ\text{C}$

Substance	$t$	$P$	$\lambda$	$R$	Lit.
Air, gas.....	$t_R^c$	760	3030	$3.65 \times 10^{-2}$	(5)
	$t_R^*$	760	3340	$2.70 \times 10^{-2}$	(5)
A, gas.....	27	760	4358	$1.34 \times 10^{-2}$	(6, 7)
CO <sub>2</sub> , liquid.....	30.5	$V. P.$	5400	$2.79 \times 10^{-4}$	(3)
	$t_c$	$P_c$	5400	$9.76 \times 10^{-4}$	(3)

\* Temperature not stated; probably room temperature.

TABLE 3.—INTENSITY RELATIVE TO AIR, OF LIGHT SCATTERED Laterally BY DUST-FREE GASES

(For absolute values,  $v$ . Table 2; for polarization of scattered light,  $v$ . Table 4.)

Pressure ( $P$ ) = ca. 1 atm.; room temperature;  $\beta = 90^\circ$ ;  $S[S_a]$  = intensity of light scattered by the gas [by air] under same conditions of  $t$  and  $P$ .

Method and source of light: (a) Visual: C-arc (40) for H and  $(C_2H_5)_2O$ . (b) Photographic: Hg-arc (7, 40); sun (11); C-arc (37, 40).

Gas	$S/S_a$	Lit.	Gas	$S/S_a$	Lit.
Air.....	1.00		O <sub>2</sub> .....	0.93*	(7)
A.....	0.79	(7)	Xe.....	5.45	(11)
H <sub>2</sub> .....	0.23	(7, 40)	N <sub>2</sub> O.....	3.40	(40)
He.....	0.017	(37)	CO <sub>2</sub> .....	2.62	(7)
Kr.....	1.95	(11)	$(C_2H_5)_2O$ .....	26.8	(40)
N <sub>2</sub> .....	1.02*	(7)			

\* Adjusted; recorded values are  $< 1$  for both N and O.

TABLE 4.—POLARIZATION OF LIGHT SCATTERED Laterally BY DUST-FREE GASES AND VAPORS

(For intensity of scattered light,  $v$ . Table 3; for variation with  $t$  and  $P$ , see Table 6.)

Pressure ( $P$ ) = ca. 1 atm.; room temperature;  $\beta = 90^\circ$ ;  $B. P.$  = temperature just above the boiling point;  $p$  = % defect in polarization = 100  $w/s$ . Values by different observers may differ in ratio of 2 to 3.

Method and source of light: (a) Visual: Sun (8, 9, 10, 16, 26, 29, 30, 33, 34); C-arc (40) for  $(C_2H_5)_2O$ . (b) Photographic: Hg-arc (40); sun (10, 11, 17, 26); tungsten arc (36); C-arc (37, 40).

Gas	$p$	Lit.
Air.....	4.3	(10, 30, 36)
A.....	0.50*	(11, 37)
H <sub>2</sub> .....	3.7	(10, 30, 36)
He.....	$< 6.5$	(37)
Kr.....	0.55	(11)
N <sub>2</sub> .....	3.6	(10, 17, 36)
Ne.....	$< 1.0$	(11)
O <sub>2</sub> .....	8.9	(10, 17, 30, 36)
Xe.....	0.55	(11)
HCl.....	1.0*	(34)
H <sub>2</sub> S.....	1.0*	(34)
NO.....	2.6	(10)
N <sub>2</sub> O.....	15.0	(10, 17, 26, 30, 36)
NH <sub>3</sub> .....	1.0*	(17, 34)
CO.....	3.4†	(10, 34, 40)
CO <sub>2</sub> .....	11.0	(10, 17, 26, 30, 36)

Vapor	$t, ^\circ\text{C}$	$p$	Lit.
CCl <sub>4</sub> , Carbon tetrachloride.....	$B. P.$	2.5	(16, 29, 40)
CS <sub>2</sub> , Carbon disulfide.....	$B. P.$	15.0	(8, 16, 26, 40)
CHCl <sub>3</sub> , Chloroform.....	$B. P.$	3.2	(16, 26, 29, 40)
CH <sub>4</sub> , Methane.....	20	1.5	(9)
CH <sub>3</sub> O, Methyl alcohol.....	$B. P.$	2.7	(16)
C <sub>2</sub> N <sub>2</sub> , Cyanogen.....	20	12.0	(40)
C <sub>2</sub> H <sub>4</sub> , Ethylene.....	20	3.0	(40)
C <sub>2</sub> H <sub>5</sub> O <sub>2</sub> , Methyl formate.....	$B. P.$	4.6	(16)
C <sub>2</sub> H <sub>6</sub> , Ethane.....	20	1.6	(9)
C <sub>2</sub> H <sub>5</sub> O, Ethyl alcohol.....	$B. P.$	1.7	(16)
C <sub>2</sub> H <sub>5</sub> O, Allyl alcohol.....	$B. P.$	5.2	(16)
C <sub>2</sub> H <sub>5</sub> O, Acetone.....	$B. P.$	4.8	(16)
C <sub>2</sub> H <sub>5</sub> O <sub>2</sub> , Ethyl formate.....	$B. P.$	3.3	(16)
C <sub>2</sub> H <sub>5</sub> O <sub>2</sub> , Methyl acetate.....	$B. P.$	4.8	(16)
C <sub>2</sub> H <sub>6</sub> , Propane.....	20	1.6	(9)
C <sub>2</sub> H <sub>5</sub> O, <i>n</i> -Propyl alcohol.....	$B. P.$	2.0	(16)
C <sub>2</sub> H <sub>5</sub> O, Isopropyl alcohol.....	$B. P.$	1.9	(16)

\* Correction for non-parallelism of incident light reduces  $p$  to about 0.8 for HCl, H<sub>2</sub>S, and NH<sub>3</sub>, and to 0.25 for A; it is suggested that for A,  $p$  is actually zero (34).

† By (16)  $p = 1.7$  for CO.



TABLE 4.—(Continued)

Vapor	$t$ , °C	$p$	Lit.	Vapor	$t$ , °C	$p$	Lit.
C <sub>4</sub> H <sub>8</sub> O, Methyl ethyl ketone.....	B. P.	4.4	(16)	C <sub>6</sub> H <sub>12</sub> , Isopentane.....	22.5	1.2	(9)
C <sub>4</sub> H <sub>8</sub> O <sub>2</sub> , Propyl formate.....	B. P.	3.5	(16)	C <sub>6</sub> H <sub>6</sub> Br, Bromobenzene.....	B. P.	7.8	(16)
C <sub>4</sub> H <sub>8</sub> O <sub>2</sub> , Ethyl acetate.....	B. P.	3.4	(16)	C <sub>6</sub> H <sub>5</sub> Cl, Chlorobenzene.....	B. P.	7.8	(16)
C <sub>4</sub> H <sub>10</sub> , <i>n</i> -Butane.....	20	1.7	(9)	C <sub>6</sub> H <sub>6</sub> , Benzene.....	B. P.	6.9	(8, 16, 26, 30, 32, 40)
C <sub>4</sub> H <sub>10</sub> O, <i>n</i> -Butyl alcohol.....	B. P.	2.8	(16)	C <sub>6</sub> H <sub>12</sub> , Cyclohexane.....	20	1.1	(33)
C <sub>4</sub> H <sub>10</sub> O, Isobutyl alcohol.....	B. P.	1.8	(16)	C <sub>6</sub> H <sub>14</sub> , <i>n</i> -Hexane.....	B. P.	3.3	(16)
C <sub>4</sub> H <sub>10</sub> O, Ethyl ether.....	B. P.	3.0	(16, 26, 29, 30, 40)		28.5	1.5	(9)
C <sub>5</sub> H <sub>10</sub> , 2-Methyl-2-butene.....	B. P.	6.1	(16)	C <sub>7</sub> H <sub>8</sub> , Toluene.....	B. P.	6.4	(16)
C <sub>5</sub> H <sub>10</sub> O, Methyl propyl ketone.....	B. P.	3.2	(16)	C <sub>7</sub> H <sub>16</sub> , Heptane.....	B. P.	3.1	(16)
C <sub>5</sub> H <sub>10</sub> O <sub>2</sub> , Propyl acetate.....	B. P.	3.2	(16)	C <sub>8</sub> H <sub>10</sub> , <i>m</i> -Xylene.....	B. P.	6.7	(16)
C <sub>5</sub> H <sub>12</sub> , <i>n</i> -Pentane.....	B. P.	3.0	(16, 30)	C <sub>8</sub> H <sub>18</sub> , Octane.....	B. P.	2.7	(16)
	22.5	1.2	(9)				

TABLE 5.—RELATIVE INTENSITY AND POLARIZATION OF LIGHT SCATTERED Laterally BY DUST-FREE LIQUIDS

(For variation with temperature and pressure, *v.* Table 6.)

$\beta = 90^\circ$ ;  $S [S_s]$  = intensity of light scattered by the liquid [by liquid (C<sub>2</sub>H<sub>5</sub>)<sub>2</sub>O at same temperature]  $W, R, G, B$  = white, red, green, blue; subscript  $i$  [ $s$ ] indicates color filter is in incident [in scattered] light (if liquid does not fluoresce the value for  $i$  = that for  $s$ ). Temperature: 18°C (8, 18, 22, 23, 24), 30°C (20, 35), 20°C (25), 35°C (29). Method and source of light: (a) Visual: Sun (8, 18, 20, 35, 41), C-arc (22), W-arc (23, 24, 25). (b) Photographic; Sun (29).

Substance	$S/S_s$	Lit.	$p = \% \text{ defect in polarization} = 100w/s$									
			$W$	Lit.	$W$	$R_i$	$R_s$	$G_i$	$G_s$	$B_i$	$B_s$	Lit.
H <sub>2</sub> O, Water.....	0.20	(20, 24, 29)	9.0	(8, 18, 20, 23, 29)	9.3	8.5	11.8	7.9	9.5	14.5	9.9	(20)
SO <sub>2</sub> , Sulfur dioxide.....	1.70	(22)	22.0	(22)								
CCl <sub>4</sub> , Carbon tetrachloride.....	1.10	(20, 29)	9.0	(8, 20, 29)								
CS <sub>2</sub> , Carbon bisulfide.....	14.0	(20, 24, 29)	70	(8, 15, 20, 24, 29, 35)	69	68.5	70			71	73	(20)
CHCl <sub>3</sub> , Chloroform.....	1.40	(20, 29)	20.0	(20, 23, 29)								
CH <sub>2</sub> Cl <sub>2</sub> , Methylene chloride.....	1.24	(20)	31	(20)								
CH <sub>2</sub> O <sub>2</sub> , Formic acid.....	1.22	(20)	55	(20)								
CH <sub>3</sub> O, Methyl alcohol*.....	0.56	(20, 24, 29)	8.0	(20, 22, 29)	8.2	6.0	8.0			12.6	7.4	(20)
C <sub>2</sub> H <sub>4</sub> Br <sub>2</sub> , Ethylene bromide.....	3.42	(20)	61	(20)								
C <sub>2</sub> H <sub>4</sub> Cl <sub>2</sub> , Ethylene chloride.....	1.44	(20)	36	(20)								
C <sub>2</sub> H <sub>4</sub> O, Acetaldehyde.....	0.89	(20)	20	(20)	20.0	18.9	19.4			21.6	19.0	(20)
C <sub>2</sub> H <sub>4</sub> O <sub>2</sub> , Acetic acid.....	1.19	(20)	47	(20)	47	47	47			48	48	(20)
C <sub>2</sub> H <sub>4</sub> O <sub>2</sub> , Methyl formate.....	1.09	(20)	28.1	(20)								
C <sub>2</sub> H <sub>5</sub> Br, Ethyl bromide.....	1.58	(20)	25.0	(20)								
C <sub>2</sub> H <sub>5</sub> S, Methyl sulfide.....	1.22	(20)	12.9	(20)								
C <sub>2</sub> H <sub>5</sub> O, Ethyl alcohol.....	0.60	(20, 24, 29)	7.3	(20, 24, 29)	6.8	5.3	7.1			10.5	6.8	(20)
C <sub>3</sub> H <sub>5</sub> Br, Allyl bromide.....	3.10	(20)	59	(20)								
C <sub>3</sub> H <sub>5</sub> Cl, Allyl chloride.....	1.47	(20)	36	(20)								
C <sub>3</sub> H <sub>5</sub> O, Allyl alcohol.....	1.22	(20)	29.3	(20)	29.3	29.6	29.4	34	31	38	37	(20)
C <sub>3</sub> H <sub>6</sub> O, Acetone†.....	0.81	(20)	26	(20, 35)								
C <sub>3</sub> H <sub>6</sub> O <sub>2</sub> , Propionic acid.....	1.24	(20)	41	(20)	41	41	42	42	41.5	49	47	(20)
C <sub>3</sub> H <sub>6</sub> O <sub>2</sub> , Ethyl formate.....	1.00	(20)	22.1	(20)	22.1	21.3	21.6			20.7	19.6	(20)
C <sub>3</sub> H <sub>7</sub> Br, Propyl bromide.....			25.0	(20)								
C <sub>3</sub> H <sub>7</sub> Cl, <i>n</i> -Propyl chloride.....	1.34	(20)	16.3	(20)								
C <sub>3</sub> H <sub>7</sub> Cl, Isopropyl chloride†.....	1.38	(20)	16.2	(20)								
C <sub>3</sub> H <sub>7</sub> O, <i>n</i> -Propyl alcohol.....	0.66	(20, 24)	8.0	(20, 24)	7.6	7.1	9.9			11.0	7.2	(20)
C <sub>3</sub> H <sub>7</sub> O, Isopropyl alcohol.....	0.60	(20)	7.2	(20)	7.2	5.0	6.7			10.7	7.2	(20)
C <sub>4</sub> H <sub>6</sub> O <sub>3</sub> , Acetic anhydride.....	1.01	(20)	43	(20)								
C <sub>4</sub> H <sub>8</sub> O, Methyl ethyl ketone†.....	0.80	(20)	17.4	(20)	17.4	16.6	18.1			25.5	18.2	(20)
C <sub>4</sub> H <sub>8</sub> O <sub>2</sub> , Butyric acid.....	1.19	(20)	40	(20)	40	36	39	41.5	44	68	55	(20)
C <sub>4</sub> H <sub>8</sub> O <sub>2</sub> , Propyl formate.....	0.94	(20)	21.0	(20)	21.0	21.0	21.1	18.1	20.4	18.6	17.7	(20)
C <sub>4</sub> H <sub>8</sub> O <sub>2</sub> , Ethyl acetate.....	0.95	(20, 22)	23.0	(20, 22)								
C <sub>4</sub> H <sub>9</sub> Br, Isobutyl bromide.....			26.4	(20)								
C <sub>4</sub> H <sub>9</sub> Cl, Isobutyl chloride.....	1.59	(22)	17.0	(20, 22)								
C <sub>4</sub> H <sub>9</sub> S, Ethyl sulfide.....	1.33	(20)	18.2	(20)								
C <sub>4</sub> H <sub>10</sub> O, <i>n</i> -Butyl alcohol.....	0.65	(20)	11.5	(20)	11.5	9.3	11.0			14.9	11.0	(20)
C <sub>4</sub> H <sub>10</sub> O, Isobutyl alcohol.....	0.76	(20, 24)	10.0	(20, 24)	11.2	7.3	11.8			16.3	9.0	(20)
C <sub>4</sub> H <sub>10</sub> O, <i>tert</i> -Butyl alcohol.....	0.69	(20)	6.2	(20)	6.2	4.1	5.8			9.2	5.6	(20)
C <sub>4</sub> H <sub>10</sub> O, Ethyl ether.....	1.00		9.0	(15, 20, 24, 29, 31)	9.1	8.0	9.3	8.3	8.9	10.9	8.8	(20)
C <sub>5</sub> H <sub>10</sub> , 2-Methyl-2-butene.....	1.54	(20)	25.8	(20)								
C <sub>5</sub> H <sub>10</sub> O, Diethyl ketone†.....	1.06	(20)	36	(20)	36	18.0	36.0			78	24.9	(20)



Substance	S/S <sub>0</sub>	Lit.	p = % defect in polarization = 100w/s									
			W	Lit.	W	R <sub>i</sub>	R <sub>s</sub>	G <sub>i</sub>	G <sub>s</sub>	R <sub>i</sub>	R <sub>s</sub>	Lit.
C <sub>5</sub> H <sub>10</sub> O, Methyl propyl ketone.....			19.6	(20)								
C <sub>5</sub> H <sub>10</sub> O <sub>2</sub> , Propyl acetate.....	0.95	(20)	21.7	(20)								
C <sub>5</sub> H <sub>12</sub> , <i>n</i> -Pentane.....	1.25	(20, 41)	7.5	(20, 23)								
C <sub>5</sub> H <sub>12</sub> , Isopentane.....	1.06	(20)	5.6	(20)								
C <sub>5</sub> H <sub>12</sub> O, <i>dl</i> -Amyl alcohol.....	0.74	(20)	11.9	(20)	11.9	9.8	12.5			27.9	10.8	(20)
C <sub>5</sub> H <sub>12</sub> O, Isoamyl alcohol.....	0.84	(24)	9.0	(15)								
C <sub>6</sub> H <sub>5</sub> Br, Bromobenzene.....	4.92	(20)	65	(20)								
C <sub>6</sub> H <sub>5</sub> Cl, Chlorobenzene.....	4.1	(20, 24)	54.0	(20, 22, 23, 24)	58	57.5	58	61	61	56	55	(20)
C <sub>6</sub> H <sub>5</sub> NO <sub>2</sub> , Nitrobenzene.....	10.5	(20)	70.0	(20, 23, 38)								
C <sub>6</sub> H <sub>6</sub> , Benzene.....	3.2	(20, 24, 29, 32)	48.0	(8, 15, 18, 20, 24, 25, 29, 32)	47	47	47	48	48	50	51	(20)
C <sub>6</sub> H <sub>7</sub> N, Aniline§.....	3.42	(20)	60	(20)								
C <sub>6</sub> H <sub>10</sub> O <sub>3</sub> , Propionic anhydride.....	1.41	(20)	44	(20)								
C <sub>6</sub> H <sub>12</sub> , Cyclohexane.....	0.87	(24)	8.0	(24)								
C <sub>6</sub> H <sub>14</sub> , Hexane.....	1.05	(24)	10.0	(20, 24)								
C <sub>7</sub> H <sub>5</sub> N, Benzonitrile.....			65.0	(38)								
C <sub>7</sub> H <sub>5</sub> Cl <sub>2</sub> , Benzal chloride.....	3.21	(20)	55	(20)	55	52	55			71	53	(20)
C <sub>7</sub> H <sub>7</sub> Cl, Benzyl chloride.....	3.50	(20)	58	(20)	58	56	61			73	54	(20)
C <sub>7</sub> H <sub>7</sub> NO <sub>2</sub> , <i>o</i> -Nitrotoluene§.....	9.4	(20)	82	(20)								
C <sub>7</sub> H <sub>7</sub> NO <sub>2</sub> , <i>m</i> -Nitrotoluene§.....	9.8	(20)	83	(20)								
C <sub>7</sub> H <sub>8</sub> , Toluene.....	3.5	(20, 24, 29)	51.0	(15, 20, 24, 29)	52.5	52.5	52	55	51	57.5	59	(20)
C <sub>7</sub> H <sub>8</sub> O, Benzyl alcohol.....	2.93	(20)	65	(20)	65	62	63			67	66	(20)
C <sub>7</sub> H <sub>16</sub> , Heptane.....	1.00	(20)	11.0	(20, 25)								
C <sub>8</sub> H <sub>10</sub> , Ethylbenzene.....	3.18	(20)	53	(20)	53	54	53	53	55	53	59	(20)
C <sub>8</sub> H <sub>10</sub> , <i>o</i> -Xylene.....			40	(20)	40	40	38			42	41	(20)
C <sub>8</sub> H <sub>10</sub> , <i>m</i> -Xylene.....	3.87	(20)	57	(20)	57	56	60			64	61	(20)
C <sub>8</sub> H <sub>10</sub> , <i>p</i> -Xylene.....	4.61	(20)	66	(20)	66	66	67			67	68	(20)
C <sub>8</sub> H <sub>10</sub> , <i>o</i> -, <i>m</i> -, <i>p</i> -Xylene  .....	3.55	(24)	52.5	(24)								
C <sub>8</sub> H <sub>16</sub> O <sub>2</sub> , Isobutyl butyrate.....	1.35	(22)	17.3	(22)								
C <sub>8</sub> H <sub>18</sub> , Octane.....	0.96	(20)	12.9	(20)								
C <sub>9</sub> H <sub>10</sub> O <sub>2</sub> , Ethyl benzoate.....	6.5	(22)	55	(22)								
C <sub>10</sub> H <sub>7</sub> Cl, $\alpha$ -Chloronaphthalene.....	18.2	(22)	78	(22)								
C <sub>10</sub> H <sub>8</sub> , Naphthalene.....	v. Table 6											
SiCl <sub>4</sub> , Silicon tetrachloride.....	1.13	(20)	5.8	(20)								

\* Liquid became dark brown. † Showed tendency to decompose. ‡ Background not perfect. § Not quite free from dust particles. || Mixture of xylenes

TABLE 6.—INTENSITY AND POLARIZATION OF LIGHT SCATTERED BY DUST-FREE LIQUIDS AND VAPORS: VARIATION WITH TEMPERATURE AND PRESSURE

Sat. vap. = saturated vapor; Unsat. = unsaturated vapor;  $G$  = vapor above critical temperature;  $G_d$  =  $G$  at constant density,  $d$ ; V. P. = pressure of saturated vapor;  $S_i$ ,  $[S_0]$ ,  $[S_{35}]$  = intensity of light scattered by the gas at  $t$ , °C,  $P$  = 1 atm. [by the gas at 0°C and  $P$  = 1 atm.], [by liquid (C<sub>2</sub>H<sub>5</sub>)<sub>2</sub>O at 35°C];  $p$  = % defect in polarization. Unit of  $P$  = 1 atm.

CO <sub>2</sub> (28)						
$P$	$S_i/S_0$	$t$ , °C	$S_i/S_0$	$P$	$S_i/S_0$	$p$
$G, t = 35^\circ\text{C}$		$G_d, d = 0.320$		Unsat., $t = 30^\circ\text{C}$		
61	290	40	1 620	68	1 078	
67	680	50	1 410	Sat. vap.		
72	1 170	Unsat., $t = 30^\circ\text{C}$		$t$ , °C	$S_i/S_0$	$p$
77.5	3 200	$P$	$S_i/S_0$	5	102	
81	4 230	15	22	10	195	
87	1 750	20	33	15	347	5.8
91	1 430	30	54	20	567	4
		40	83	24	1 030	
$G_d, d = 0.320$		50	140	25	1 190	3
$t$ , °C	$S_i/S_0$	55	197	26	1 890	
32	4 550	60	307	28	3 560	
35	2 730	65	665	30	8 000	1.5

CO<sub>2</sub>.—(Continued)

Liquid			
$t$ , °C	$P$	$S_i/S_0$	$p$
5	V. P.	360	
10	V. P.	480	14
15	V. P.	680	10
15	51	663	
15	68	522	
15	76	470	
15	82	428	
20	V. P.	990	8
20	80		10
20	92		13
23	V. P.	1 280	
25	V. P.	1 880	5
25	V. P.	2 100	
25	68	1 650	
25	74	1 200	
25	83	778	
25	90		9
25	92	600	
27	V. P.	2 950	3
29	V. P.	6 200	3
30	V. P.	11 000	
30.5	V. P.	22 500	
30.5	72.5	5 480	
30.5	76.5	2 610	
30.5	84.0	1 097	
30.5	86.5	940	
31	V. P.	35 000	

C<sub>4</sub>H<sub>10</sub>O, Ethyl ether (31)

$t$ , °C	$S_i/S_{35}$
$G$	
194	378
196	172
198	126
200	84
202	64
212.5	27
217	21

Sat. vap.\*

$t$ , °C	$S_i/S_{35}$
33	0.038
54	0.075
75	0.150
91	0.22
108	0.45
123.5	0.71
144.5	1.31
164	2.7
170.5	3.9
179.2	9.1
183.5	13.0

C<sub>4</sub>H<sub>10</sub>O.—(Cont'd)

Sat. vap.*	
$t$ , °C	$S_i/S_{35}$
186.5	21
190	42
191	63

Liquid		
$t$ , °C	$S_i/S_{35}$	$p$
33	1.00	8
61	1.23	8
80	1.85	7
91	1.90	

Sat. vap.*		
$t$ , °C	$S_i/S_{35}$	$p$
104	2.3	7
125	3.0	7.5
139	3.8	5
145	4.9	3
153	6.3	1.7
170	12.0	1.7
179	22	
185	38	1.3
190.5	82	1.3

\* From  $t = 160$  to  $200^\circ\text{C}$ ,  $p$  varies from 1.3 to 1.0; no change in passing through critical temperature.



$C_5H_{12}$ , <i>n</i> -Pentane <sup>(41)</sup>			$C_5H_{12}$ —(Cont'd)			$C_5H_8$ —(Cont'd)			$C_7H_{16}$ , Heptane			$C_7H_{16}$ —(Cont'd)			$C_{10}H_8$ , Naphthalene		
$t, ^\circ C$	$S_t/S_{25}$	$p$	$t, ^\circ C$	$S_t/S_{25}$	$p$	$t, ^\circ C$	$S_t/S_{25}$	$p$	$t, ^\circ C$	$S_t/S_{25}$	$p$	$t, ^\circ C$	$S_t/S_{25}$	$p$	$t, ^\circ C$	$S_t/S_{25}$	$p$
Liquid			Liquid			Liquid (32)			Liquid (25)			Liquid (25)			Liquid (25)		
200	48.5		36.5	1.61	7.2	35	3.2	43	20	1.00	12.7	240	10.1	2.0	80	1.00	71.0
203	30.8		80		7.2	125	3.67	32	100	1.30	10.0	250	13.4	1.7	200	1.04	63.5
210	20.8		86.6	2.84	6.7	182	5.48	19	200	3.97	3.8	260§	16.8	1.65	300	1.30	41.0
214	15.2		103.8	3.40		205	7.21	14	225	6.8	2.6	270§	28.1	1.55			
			117.0	4.25	5.2	228	11.0	9.5									
			128.0	5.36	5.2	268	20.5	3.0									
			138.0	6.37		283	102	2.8									
			148.6	8.18	1.7												
			156.8	9.10	1.5												
			173		1.5												
Sat. vap.																	
87	0.235																
125.2	0.73																
137	1.20																
145	1.95	2.5															
149	2.10																
154	2.42																
155.4	2.66																
167	3.90	2.0															
172	5.88																
183	13.4	1.5															
187	17.8																
189	22.1																
190.5	23.3																
193	30.8																
196	70.8	1.5															

§ At critical temperature  $S_t/S_{25}$  is very great.

## LITERATURE

(For a key to the periodicals see end of volume)

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## SPECTRAL ABSORPTION OF LIGHT AND HEAT BY PURE INORGANIC SUBSTANCES AND MISCELLANEOUS MATERIALS (NONMETALS)

JEAN BECQUEREL AND J. ROSSIGNOL

Order of Substances.—Atmospheric air, elementary substances, pure inorganic compounds, minerals of variable composition.

### ABSORPTION OF ATMOSPHERIC AIR

$w$  = equivalent thickness of liquid  $H_2O$  in a column of air 117 m long ( $P = 1$  atm.,  $t < 40^\circ C$ ) = volume of liquid  $H_2O$  obtained by condensing the  $H_2O$  vapor contained in a column of air of unit sectional area and 117 m long.  $O$  = opacity of the atmosphere (source of light at zenith) =  $I_0/I$ ;  $I_0/I_0$  = intensity of radiation beyond atmosphere [at surface of earth].  $I = I_0 e^{-k(10)^w}$ ;  $l$  = length of path in which intensity is reduced from  $I_0$  to  $I$ . All  $I$ 's refer to radiant energy, not to its visibility.

Unit of  $k(10)^w = 1 \text{ cm}^{-1}$ ; of  $l = 1 \text{ cm}$ ; of  $w = 1 \text{ cm}$ ; of  $\lambda = 1 \mu = 10^4 \text{ \AA} = 10^{-4} \text{ cm}$ .

$\lambda$	$k$	$w$	0.008	0.082
Dry air (12), $w = 0$ , $n = -3$				
0.186	4.82			
Moist air (7), $n = -5$				
$w$	0.008	0.082		
$\lambda$	$k$	$k$		
1.3 to 1.75	0.54	1.7		
1.75 to 2.2	1.25	2.9		
2.2 to 3.2	2.3	4.5		
3.2 to 4.0	2.1	3.95		
4.0 to 4.9	3.3	5.9		
4.9 to 5.4	1.7	4.7		
5.4 to 5.9	5.4	16		
5.9 to 6.4	8.7	30		
6.4 to 7.0	9.8	30		
7.0 to 8.0	2.5	8.3		

Moist air (7), $n = -5$				
$w$	0.003	0.03	0.3	3.0
$\lambda$	$k$	$k$	$k$	$k$
3 to 4	0.9	3.05	5.9	12
4 to 5	1.4	5.1	10.3	26
5 to 6	1.5	4.8	9.2	26
6 to 7	5.1	16	26	>40
7 to 8	1.2	4.7	16	>40
8 to 9	< 0.1	0.17	4.4	5.9
9 to 10	< 0.1	< 0.1	< 0.1	1.4
10 to 11	< 0.1	0.17	0.44	4.4
11 to 12	< 0.1	< 0.1	0.35	0.9
12 to 13	< 0.1	< 0.1	1.2	1.9
13 to 16	>40	>40	>40	>40
16 to 20	20	>40	>40	>40
20 to 30	10(?)	14(?)	20(?)	>40
30 to 40	>40(?)	>40(?)	>40(?)	>40
40 to 50	>40	>40	>40	>40

Opacity of atmosphere* (6)					
$\lambda$	$\log_{10} O$	$\lambda$	$\log_{10} O$	$\lambda$	$\log_{10} O$
0.2898	6.36	0.2931	4.36	0.2997	2.22
.2906	5.78	.2936	4.12	.3022	1.77
.2912	5.39	.2946	3.73	.3052	1.40
.2917	5.08	.2956	3.33	.3104	0.99
.2922	4.82	.2963	3.10	.3143	0.84

\* Average conditions, no clouds, value of  $w$  is not indicated.



# ABSORPTION OF PURE NON-METALLIC INORGANIC SUBSTANCES AND MINERALS

$I = I_0 e^{-k(10)^n}$ ,  $l$  = length of path in which intensity is reduced from  $I_0$  to  $I$ ;  $I$  and  $I_0$  refer to radiant energy, not to its visibility;  $d$  = density. For metals, v. p. 248.

Unit of  $k(10)^n$  = 1 cm<sup>-1</sup>; of  $l$  = 1 cm; of  $P$  = 1 mm of Hg; of  $d$  = 1 g cm<sup>-3</sup>; of  $\lambda$  = 1  $\mu$  = 10<sup>4</sup> Å = 10<sup>-4</sup> cm;  $t$  is °C.

Br (24),  $t = 16^\circ$ ,  
 $P = 66$ ,  $n = -2$

$\lambda$	$k$
0.356	10.6 ± 0.1
.3641	22.4 ± 0.2
.3713	38.9 ± 0.4
.3838	75.3 ± 0.8
.3900	98 ± 1
.4009	129 ± 1
.4070	136 ± 1
.421	135 ± 1
.433	128 ± 1
.449	112 ± 1
.487	76 ± 4
.510	57 ± 3
.526	38 ± 2
.546	23 ± 1
.572	12.1 ± 0.6
.608	3.1 ± 0.2
$t = 320^\circ$ ,	
0.354	21.3 ± 0.4
.377	65 ± 1
.406	115 ± 2
.428	122 ± 2
.439	115 ± 2
.471	85 ± 2

Br.—(Cont'd)

$\lambda$	$k$
0.510	51 ± 1
.557	19.6 ± 0.4
$t = 620^\circ$	
0.344	18.3 ± 0.4
.358	37.6 ± 0.8
.379	74 ± 1
.395	97 ± 2
.420	113 ± 2
.433	113 ± 2
.459	97 ± 2
.484	74 ± 1
.530	37.9 ± 0.8
.577	16.3 ± 0.3

C.—(Continued)

$\lambda$	$k$
0.430	11
.550	<1
.600	3
C, Graphite (37)†	
0.430	1455 ± 25
.450	1410 ± 25
.500	1305 ± 25
.550	1225 ± 20
.600	1155 ± 20
.650	1110 ± 15
.700	1070 ± 15

C, Amorphous (30)†

$\lambda$	$k$
0.430	198.0 ± 1.0
.450	188.0 ± 1.0
.480	174.5 ± 1.0
.500	166.0 ± 1.0
.530	155.5 ± 1.5
.550	149.5 ± 1.5
.580	141.5 ± 1.0
.600	137.0 ± 1.0
.630	131.5 ± 0.5

\*  $n = -2$ . †  $n = +3$ .

Cl,  $t = 0^\circ$ ,  $P = 760$ ,  $n = -2$

$\lambda$	$k$ (21)	$k$ (10)	$k$ (24)	$\lambda$	$k$ (21)	$k$ (10)	$k$ (24)
0.226	62			0.338			568 ± 11
.230	62			.340	527		
.235	62			.346			529 ± 10
.245	43			.350	477		
.250	43			.3525			456 ± 9
.254		2.5		.3593			366 ± 7
.255	50			.360	422		
.260	60			.365			280 ± 6
.265		12.8		.366		284	
.270	80			.370	370		
.275	93			.373			192 ± 4
.280	123	77.1		.380	212		
.285	157			.381			130 ± 2
.289		74.8		.385	158		
.290	187			.390	183		
.295	211			.405	277	41.6	
.297		278		.410	211		
.300	300			.411			3.7 ± 0.1
.303		367		.435	117		
.310	415			.436		17.1	
.313		571		.472		4.2	
.3142			129 ± 2	.480		2.4	
.3192			225 ± 4	.496		1.05	
.320	508			.509		0.47	
.321			315 ± 6	.545	61		
.3238			445 ± 9	.546		0.018	
.327			529 ± 10	.579		0.003	
.330	560			.580	82		
.331			565 ± 11	.614		0.51	
.334		684		.643		0.41	

I, Solid (17),  
 $n = +3$

$\lambda$	$k$
0.325	318
.360	462
.400	466
.440	437
.470	384
.510	300
.590	120

I, Gas (32),  $n = -2$

$t$	48°	88°	400°
10 000d	0.254	2.5	2.5
$\lambda$	$k$	$k$	$k$
0.440	0.8		
.445	4.0		
.450	6.5		19
.455	9		23
.460	10	13	27
.465	12	17	32
.470	13	22	37
.475	15	29	45
.480	16	40	55
.485	17	54	64
.490	19	64	68
.495	20	71	71
.500	21	75	72
.505	20	77	71
.510	19	76	68
.515	16	68	60
.520	14	52	48
.525	13	42	38
.530	13	36	35
.535	13	32	34
.540	14	29	34
.545	14	27	33
.550	14	26	31
.555	15	25	29
.560	15	24	26
.565	14	23	23
.570	13	22	21
.575	11	21	20
.580	9	20	19
.585	8	18	20
.590	7	16	20
.595		14	

N<sub>2</sub>(12),  $t = 0^\circ$ ,  
 $P = 760$ ,  $n = -5$

$\lambda$	$k$
0.186	109

O<sub>2</sub>(12),  $t = 0^\circ$ ,  
 $P = 760$ ,  $n = -3$

$\lambda$	$k$
0.186	20.6
0.193	3.35

O<sub>3</sub>,  $P = 760$  ( $t + 273$ )/273,  $n = 0$ (35)

$t$	1220°	1400°
$\lambda$	$k$	$k$
0.210	0.33	0.73
.220	0.26	0.50
.230	0.19	0.32
.239	0.13	0.22
.254	0.06	0.13
$t$	1580°	1760°
$\lambda$	$k$	$k$
0.210	>4.5	>4.5
.220	0.92	1.77
.230	0.54	0.97
.239	0.37	0.67
.254	0.21	0.42

O<sub>3</sub>, Ozone,  $t = 0^\circ$ ,  
 $P = 1$ ,  $n = 0$

$\lambda$	$k$ (19)	$k$ (13)	$k$ (5)
0.193	26.9		
.200	17.9		
.210	26.4		
.220	44.3		
.230	112		115
.240	241	260	219
.250	284	374	276
.254		430	
.260	291		276
.265		341	
.270	267	174	209
.280	169	112	106
.290	89	56	38
.300	69.8	18	10.6
.310			2.83
.320			0.81
.330			0.21
.340			0.06

S, Gas (11),  $t = 450^\circ$ ,  
 $d = 67 \times 10^{-6}$ ,  
 $n = -2$

$\lambda$	$k$
0.435	27
.460	20
.500	15
.550	7
.610	<0.5

Se, Vitreous,  
 $n = +3$

$\lambda$	$k$ (36)	$k$ (17)
0.260		613
.275		611
.300		652
.325		580
.360		480
.400	726	380
.415	660	
.425	594	
.440	525	300
.470	460	252
.490	382	
.510		203
.515	273	
.550	176	
.590	95.5	170
.640	47.1	
.670		84
.710	21.4	
.760	10.1	

Se, Gas (11),  $t = 700^\circ\text{C}$ ,  $d = 10.9 \times 10^{-5}$ ,  $n = -2$

$\lambda$	$k$
0.435	43
.450	39
.510	23
.525	19
.580	<0.5

H<sub>2</sub>O, Gas (3),  $t = 0^\circ$ ,  
 $P = 760$ ,  $n = -3$

$\lambda$	$k$
1.35	4.6
1.37	8.7

H<sub>2</sub>O.—(Cont'd)

$\lambda$	$k$
1.404	19.3
1.45	11.4
1.50	4.2
1.80	3.7
1.85	18.7
1.885	25.8
1.935	18.8
1.97	12.0
2.0	3.6
2.55	25.8
2.585	64.4
2.618	90
2.65	59

H<sub>2</sub>O, Liquid (12),  
 $n = -2$

$\lambda$	$k$
0.186	68.8
.193	16.6
.200	9.0
.210	6.1
.220	5.7
.230	3.4
.240	3.2
.260	2.5
.300	1.5

$n = -3$

$\lambda$	$k$ (1)	$k$ (4)	$k$ (2)
0.415		0.35	
.420		0.32	
.430*		0.23	
.440		0.16	
.450	0.20	0.12	
.460		0.11	
.470		0.12	
.480	0.20	0.13	
.490		0.14	0.02
.500	0.20	0.15	
.510	0.22	0.16	
.520	0.18	0.18	0.02
.530	0.08	0.19	0.03
.540*	0.09	0.21	0.11
.550	0.36	0.23	0.26
.560	0.30	0.27	0.40
.570	0.20	0.33	0.43
.580*	0.26	0.42	0.50
.590	0.78	0.70	0.89
.600	1.60	1.07	1.65
.610	1.90	1.18	2.20
.620	2.12	1.24	2.40
.630	2.24	1.30	2.50
.640	2.35	1.37	2.75
.650	2.50	1.48	3.05
.660	2.80	1.62	3.25
.670	3.00	1.83	
.680	3.40	2.10	
.690	4.00	2.50	
.700	5.50	3.00	
.710	7.90	3.90	
.720	11.5	4.70	
.730	17.5	5.70	
.740	23.0		
.75	24.1		
.80	20.4	(3)	
.85		69	
.90		161	
.95		311	
.995	416	472	
1.05		368	

\* Liquid H<sub>2</sub>O, (16)

$\lambda$	$k$	$k$	$k$
0.4358	0.5461	0.5780	
0.12	0.34	0.64	



H <sub>2</sub> O.—(Cont'd)			H <sub>2</sub> O.—(Cont'd)			CO <sub>2</sub> —(Cont'd)			AgI.—(Cont'd)			CaF <sub>2</sub> —(Cont'd)			NaCl.—(Cont'd)			
n = 0			λ			λ			λ			λ			λ			
λ	k <sup>(1)</sup>	k <sup>(2)</sup>	λ	k <sup>(1)</sup>	k <sup>(2)</sup>	λ	k		λ	k		λ	k		λ	k		
1.05		0.368	11.0		12.0	4.10	12.0		0.350	111	± 2							
1.085		0.333	12.0		25.9	4.20	33.5		.355	104	± 2	n = 0 (25)						
1.095	0.188		13.0		28.9	4.25	50		.360	101	± 2	24	> 8.5		6 to 8	< 0.001		
1.13		0.60	15.0		35.7	4.30	61		.365	98	± 2	52	5.7		9 to 11	0.005		
1.17		1.12	18.0		29.9	4.33	63		.370	95	± 2	61	5.02		12	0.007		
1.21		1.30	24		(25)	4.35	60		.375	93	± 2	CaCO <sub>3</sub> , Calcite			13	0.024		
1.243	1.22		52		> 0.46	4.40	38		.380	90	± 2	n = 0 (23)			14	0.071		
1.25		1.24	61		> 0.46	4.45	27		.385	88	± 2	0.215	3.36		15	0.167		
1.281	1.17		108		(29)	4.50	20		.390	87	± 2	.230	1.25		16	0.41		
1.30		1.48	314		4.23	4.60	11.2		.395	86	± 2	.240	0.58		17	0.66		
1.35		2.14	HBr, Gas (33); cf. (38)			4.69	1.2		.400	85	± 2	.250	0.40		18	1.29		
1.40		3.05	t = 0°, P = 760,			CS <sub>2</sub> , Liquid (25),			.405	85	± 2	.260	0.29		19	2.34		
1.45		20.1	n = -3			n = 0			.410	88	± 2	.270	0.20		20.7	5.1		
1.475		29.9	λ	k		24	5.1		.415	101	± 2	.280	0.16		n = 0 (25)			
1.50	38.4	28.4	0.207	44.4		52	0.20		.420	128	± 3	k <sub>0</sub> †, n = 0 (18)			24	10.7		
1.56		15.0	.253	3.20		61	0.30		.4227	138	± 3	1.02	0.00		52	> 16		
1.60		9.2	HI, Gas (34); cf. (38)			SiO <sub>2</sub> , v. Vol. VI			.425	117	± 2	1.25	0.00		61	> 16		
1.677		5.2	t = 0°			AgCl (25), n = 0			.430	33	± 10	1.45	0.00		KCl, Sylvite			
1.708	11.4		P = 760, n = -3			24	4.8		.435	10	± 3	1.72	0.03		n = 0 (27)			
1.75		7.5	0.207	62.2		52	> 27		.440	5.1 ± 1.5		2.07	0.13		10	0.012		
1.85		12.7	.253	29.0		61	> 27		.445	3.1 ± 1.0		2.11	0.74		11	0.010		
1.90		31.5	SO <sub>2</sub> , Gas (8), t = 0°,			AgBr, Fused (31),			.450	1.1 ± 0.3		2.30	1.92		12	0.005		
1.95		86	P = 760, n = 0			n = +3			Fe <sub>2</sub> O <sub>4</sub> , Magnetite			2.44	3.00		13	0.005		
1.956	123		0.220			57	0.360	6.7	(14), n = +3			2.53	1.92		14	0.025		
1.97		104	.2225			18.5	λ	k	λ	k		2.60	1.21		15	0.047		
2.00		70	.280			32	0.440	242	0.440	242		2.65	1.74		16	0.066		
2.08		35.6	.285			35.5	.370	5.0	.460	222		2.74	2.36		17	0.081		
2.10		31.6	.285			35.5	.380	3.8	.480	201		2.83	1.32		18	0.148		
2.147	27.8		.290			39.5	.390	2.79	.500	183		2.90	0.70		19	0.277		
2.15		24.7	.295			42.5	.400	2.00	.520	169		2.95	1.80		20.7	0.535		
2.237		19.6	.300			41	.410	1.38	.540	158		3.04	4.71		24	1.86		
2.30		25.9	.305			34	.420	0.90	.560	150		3.30	22.7		Biotite (15), n = 0,			
2.35		33.0	.310			20	.430	0.60	.580	145		3.47	19.4		t = 25°			
2.40		40.3	.315			6.3	.440	0.41	.600	138		3.62	9.6		1.52	42.0		
	n = +2		.320			4.0	.450	0.27	.620	133		3.80	18.6		1.82	19.0		
λ	k <sup>(1)</sup>	k <sup>(2)</sup>	NO, Gas (12), t = 0°,			AgI (28), n = +3			.640	126		3.98	∞		2.25	8.1		
2.6		5.32	P = 760, n = -3			λ	k	λ	.660	118		4.35	6.6		2.76	6.8		
2.8		22.4	0.200			142.2	0.215	85.3 ± 1.9	.680	109		4.52	14.3		2.91	6.2		
3.0		73.3	.210			95.1	.220	88.0 ± 2.0	.700	98		4.66	11.6		2.96	6.1		
3.02	27.3		.220			84.1	.225	87.7 ± 2.0	Fe <sub>2</sub> O <sub>3</sub> .CuO, Cupro-			4.83	6.1		3.0	4.7		
3.2		66.4	.230			52.1	.230	88.5 ± 2.0	ferrite (14), n = +3			5.25	8.0		3.04	4.6		
3.4		14.4	.240			24.0	.235	88.8 ± 2.0	0.440	270		k <sub>0</sub> †, n = 0 (18)	2.49	0.14		3.12	4.2	
3.6		4.9	.250			3.18	.240	96.3 ± 2.1	.460	230		2.87	0.08		3.22	3.4		
3.93	2.04		.300			0.80	.245	99.5 ± 2.1	.480	200		3.00	0.43		3.85	3.6		
4.5		4.47	CO <sub>2</sub> , Gas (12), t = 0°,			λ			.500	179		3.28	1.32		4.06	3.8		
4.70	5.45		P = 760, n = -3			λ	k	λ	.520	162		3.38	0.89		n = 0, t = 250°			
5.27	3.08		0.186			7.64	.250	102 ± 2	.540	145		3.59	1.79		1.50	63		
5.42	3.42		.210			95.1	.255	104 ± 2	.560	118		3.76	2.04		1.80	42		
5.47	3.35		.220			84.1	.260	113 ± 2	.580	90		3.90	1.17		2.21	34		
5.8		9.1	.230			52.1	.265	138 ± 3	.600	80		4.02	0.89		2.72	22		
6.0		21.4	.240			24.0	.270	276 ± 6	.620	72		4.41	1.07		2.92	19		
6.09	25.3		.250			3.18	.2712	282 ± 6	.640	64		4.67	2.40		3.0	17		
6.2		20.0	.300			0.80	.275	259 ± 5	.660	55		4.91	1.25		3.19	16		
6.5		10.3	CO <sub>2</sub> , Gas (12), t = 0°,			λ			.680	47		5.04	2.13		3.4	13		
6.73	8.7		P = 760, n = -3			λ	k	λ	.700	38		5.34	4.41		3.6	12		
6.765	8.8		0.186			7.64	.250	102 ± 2	CaF <sub>2</sub> , Fluorite			5.50	12.8		3.8	10		
6.92	8.2		.210			95.1	.255	104 ± 2	n = 0 (23)			†k <sub>0</sub> for ordinary and k <sub>0</sub> for extraordinary ray.			4.01	11		
6.955	8.3		.220			84.1	.260	113 ± 2	n = 0 (26)			NaCl, Rock salt			Mica			
7.0		8.9	.230			52.1	.265	138 ± 3	6			n = 0 (23)			n = +2 (25)			
7.11	8.2		.240			24.0	.270	276 ± 6	8			0.186			24			1.8
7.275	8.45		.250			3.18	.2712	282 ± 6	9			.210			52			3.2
7.41	7.9		.300			0.80	.275	259 ± 5	10			.231			61			3.0
7.44	8.1		λ			k	.275	259 ± 5	11			.280			108			3.3
7.49	8.0		1.96			0.3	.280	235 ± 5	12						314			1.1
7.545	8.1		2.12			0.3	.285	220 ± 4										
7.65	7.65		2.28			0.03	.290	208 ± 4										
7.70	7.85		2.40			1.7	.295	198 ± 4										
7.83	7.65		2.50			5.7	.300	188 ± 4										
7.88	7.75		2.60			11.5	.305	179 ± 4										
7.94	6.9		2.70			13.4	.310	171 ± 4										
8.0		7.55	2.80			11.4	.315	167 ± 4										
8.065	7.85		2.90			6.5	.3191	167 ± 4										
8.13	7.65		3.00			2.7	.320	167 ± 4										
8.16	7.85		3.10			1.1	.325	165 ± 4										
8.22	7.15		3.20			< 0.01	.330	158 ± 3										
8.28	7.65		3.80				.335	144 ± 3										
8.38	6.95		3.90			1.3	.340	124 ± 3										
8.43	7.55		4.0			4.1	.345	117 ± 2										
8.49	7.25																	
9.0		7.0																
10.0		7.05																



## LITERATURE

(For a key to the periodicals see end of volume)

- (1) Aschkinass, 8, 55: 401; 95. (2) d'Aufsch, 8, 13: 678; 04. (3) Dreisch, 96, 30: 200; 24. (4) Ewan, 3, 23: 317; 92. (5) Fabry and Buisson, 34, 156: 782; 13. (6) Fabry and Buisson, 51, 2: 197; 21. 21, 54: 297; 21. (7) Fowle, 302, 68: No. 8; 17. (8) Garrett, 3, 31: 505; 16. (9) Goldhammer, *Dispersion und Absorption des Lichtes*. Leipzig, Teubner, 1913.
- (10) Halban and Siedentopf, 7, 103: 71; 22. (11) Koenigsberger and K pferer, 8, 37: 601; 12. (12\*) Kreusler, 8, 6: 412; 01. (13) Kr ger and Moeller, 63, 13: 729; 12. (14) L ria and Zakrzewski, 180, 1910A: 278. 10, 1: 93; 10. (15) Martin, 5, 96: 185; 19. (16) Martin, 50, 26: 471; 22. (17) Meier, 8, 31: 1017; 10. (18) Merritt, 2, 2: 424; 95. (19) Meyer, 8, 12: 849; 03.

- (20) Owen, 121, 63: 504; 12. (21) Peskov, 53, 47: 918; 15. (22) Peter, 66, 15: 358; 23. (23) P f ger, 63, 5: 215; 04. (24) Ribaud, 6, 12: 107; 19. (25) Rubens and Aschkinass, 8, 63: 241; 98. (26) Rubens and Nichols, 2, 4: 314; 97. (27) Rubens and Nichols, 2, 5: 98; 97. (28) Schell, 8, 35: 695; 11. (29) Schmidt, 8, 42: 415; 13.
- (30) Senftleben and Benedict, 8, 54: 65; 17. (31) Slade and Toy, 5, 97: 181; 20. (32) Vogt and Koenigsberger, 96, 13: 292; 23. (33) Warburg, 76, 1916: 314. (34) Warburg, 76, 1916: 300. (35) von Wartenberg, 63, 11: 1168; 10. (36) Wood, 3, 3: 607; 02. (37) Zakrzewski, 180, 1910A: 116. 10, 1: 93; 10. (38) Tingey and Gerke, 1, 43: 1838; 26.

\* Errors in computation have been corrected by Becquerel and Rossignol.

## SPECTRAL FILTERS

K. S. GIBSON

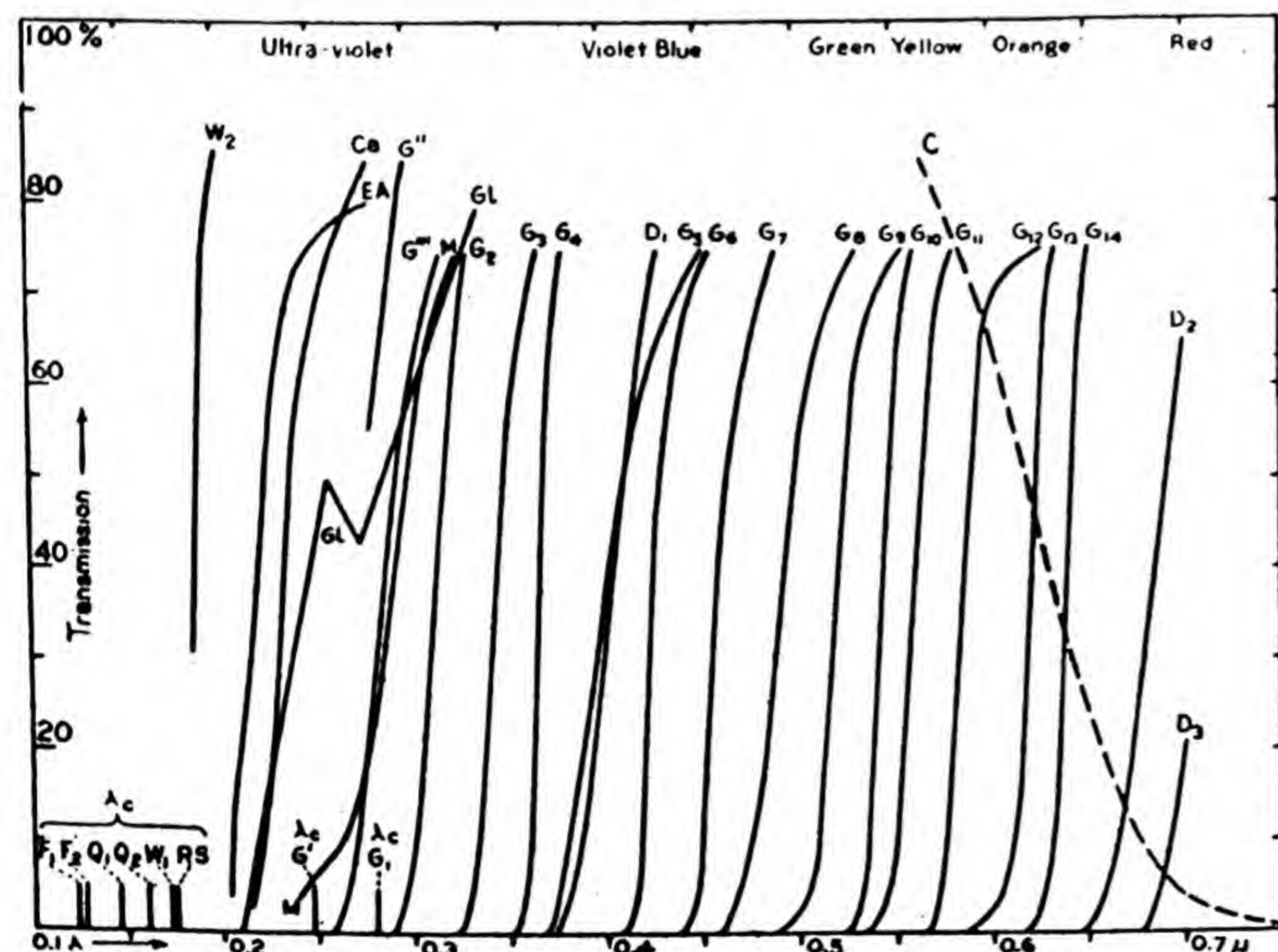
The filters here considered cover the spectral regions commonly designated as ultra-violet (UV), visible (v), and infra-red (IR). The numerical data are based on quantitative measurements, but, owing to the variability of much of the material or to the insufficiency of the details given by the authors, they are, in general, to be considered as illustrative only. As a rule, only such glasses, crystalline material, and simple, well-known substances as have a relatively sharp transition between the regions of free transmission and of strong absorption are noted. Many of these filters, especially those having selective transmission between  $\lambda = 0.3\mu$  and  $0.7\mu$ , can be practically duplicated by means of dyes and other solutions.

## Filters

Spectral filters may conveniently be divided into three classes:

**Class 1.**—Strong absorption if  $\lambda$  is less than a certain value,  $\lambda_c$ , and free transmission over a wide adjacent range where  $\lambda > \lambda_c$ .

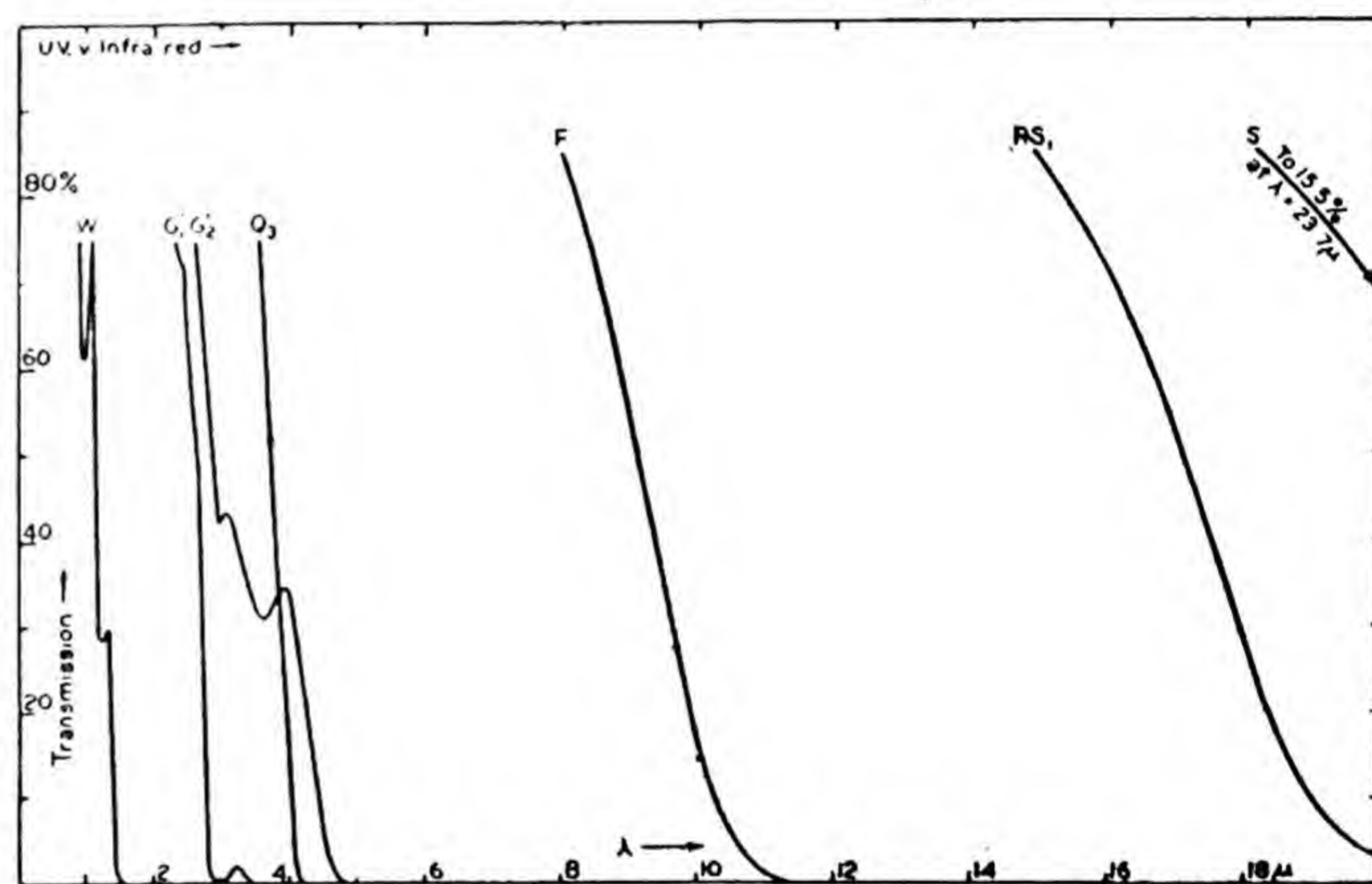
Radiation in range  $0.002\mu < \lambda < 0.12\mu$  is not transmitted by any solid or liquid; of ordinary gases,  $H_2$  is the most and  $O_2$  is the least transparent in this region (31). The UV-limit of transmission of air is near that of  $H_2O$  ( $\lambda_c$  of  $W_1$ , ca.  $\lambda = 0.17\mu$ ) (31). Curves similar to those of Fig. 1 may be obtained between  $0.2\mu$  and  $0.35\mu$  by use of organic liquids (1, 2, 47), between  $0.3\mu$  and  $0.7\mu$  by use of solutions or of dyed films of gelatin (15), and in IR (4, 43, 46) by use of thin layers of lampblack or various thicknesses of black paper or cardboard.

FIG. 1.—Filters of Class 1: Transmission near  $\lambda_c$ .

For descriptions of filters, see Table 1; C is of Class 2. For  $F_1$ ,  $F_2$ ,  $Q_1$ ,  $Q_2$ ,  $W_1$ ,  $RS$ ,  $G'$  and  $G_1$ , only value of  $\lambda_c$  is indicated; curves for C, Ca, EA,  $G''$ ,  $G_1$  and  $W_1$  have been corrected for surface and window losses (reflection and absorption), other curves are uncorrected.  $0.1\mu = 10^{-4} \text{ cm} = 1000 \text{ \AA}$ .

**Class 2.**—Strong absorption over wide region in which  $\lambda$  is greater than  $\lambda_c$ , and free transmission over a wide adjacent range for which  $\lambda < \lambda_c$ .

For the substances considered here, the long wave-length boundary of the absorption lies far in the IR, but transmission at still greater values of  $\lambda$  may be of much importance. For summary of such data, and bibliography to 1921, see (46). Crystalline  $SiO_2$  is notably transparent if  $\lambda > 50\mu$ ; if sufficiently thin, many substances transmit if  $\lambda > \text{ca. } 100\mu$ , and there is considerable transmission through 1 mm of  $CaF_2$ ,  $KCl$ ,  $NaCl$ , and amorphous  $SiO_2$ , but there seems to be no transmission through this thickness of  $H_2O$  or of glass.

FIG. 2.—Filters of Class 2: Transmission near  $\lambda_c$ .

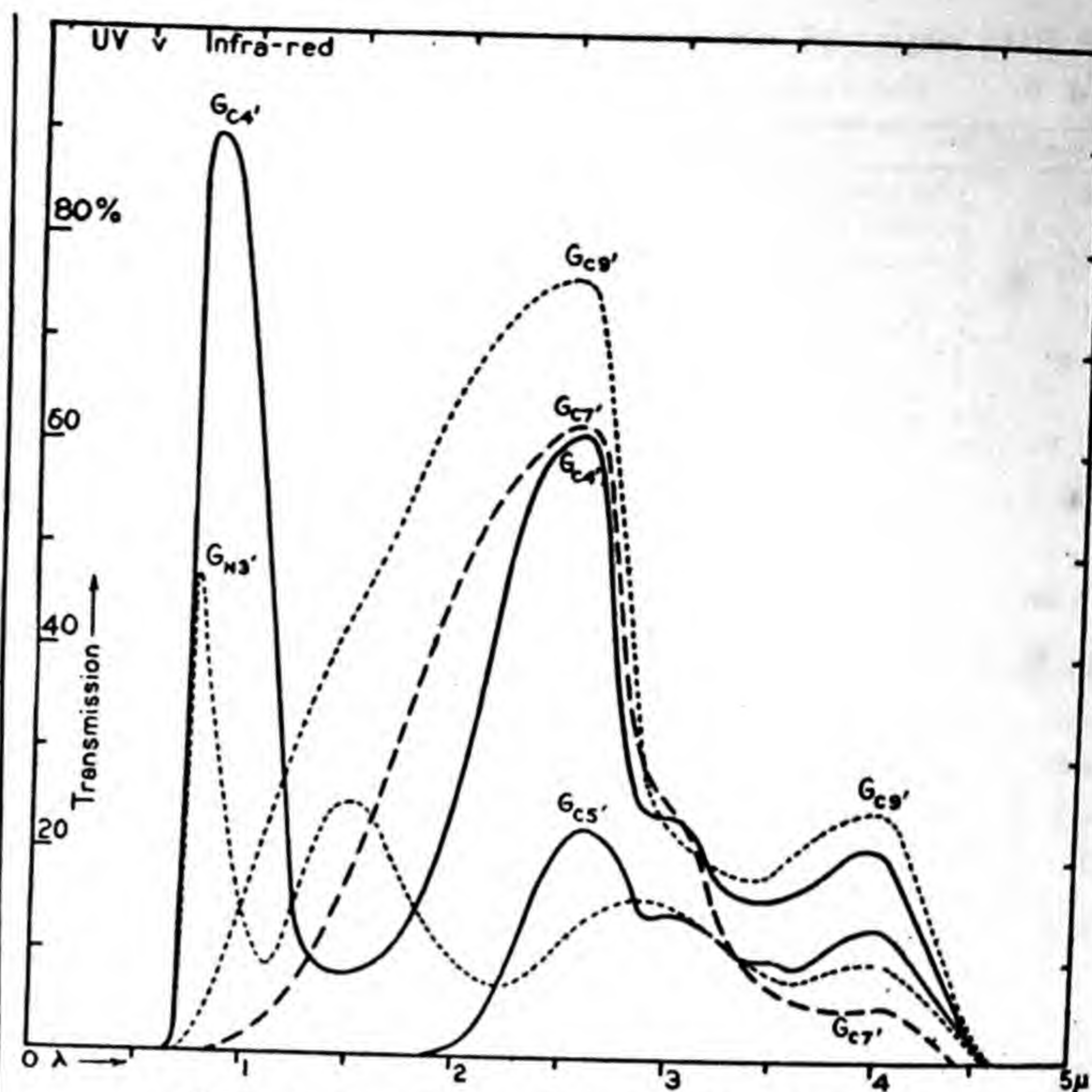
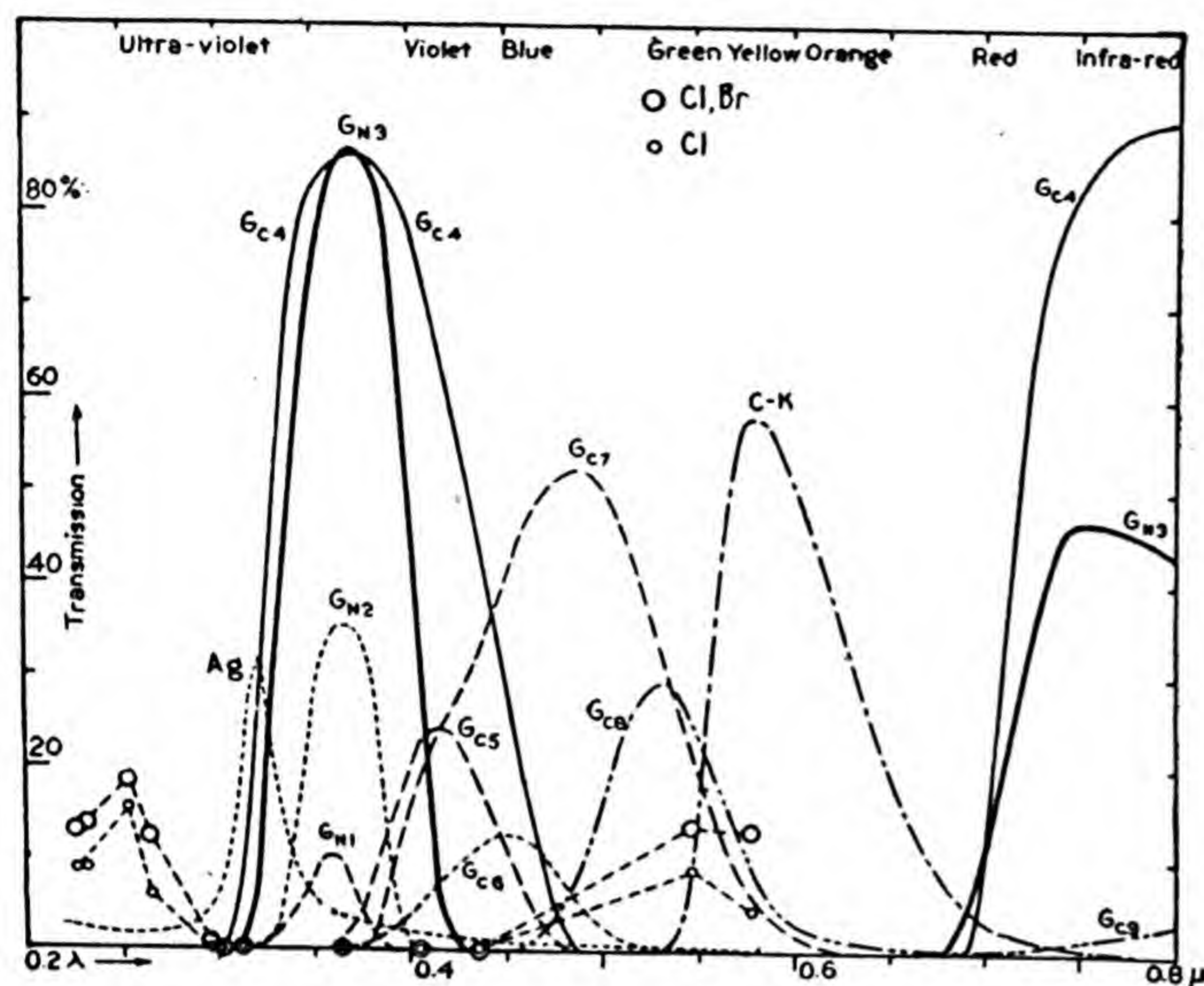
See also C of Fig. 1. For description of filters, see Table 1. Curves for F, RS, and S have been corrected for reflection at surfaces, others are uncorrected.  $1\mu = 10^{-4} \text{ cm} = 10,000 \text{ \AA}$ .

Aqueous ( $H_2O$ ) solutions of Cu salts completely absorb the IR while freely transmitting the visible spectrum (cf. C, Fig. 1); at least 2 cm of the solution should be used (6, 19). For glasses which visually approximate filter C, see (16, 20, 22); they all transmit some IR (11, 12). For isolating the region  $\lambda < 0.3\mu$ , see Class 3.

**Class 3.**—Strong absorption except over certain narrow regions of the spectrum.

In Figs. 3, 4 and 5 are shown the transmissions of certain filters of this class. By a suitable choice of these filters, assisted by those of classes 1 and 2 as may be necessary, it is possible to isolate any one of many narrow spectral regions (19). No known filter transmits only the region  $\lambda < 0.3\mu$ ; the best consists of quartz ( $SiO_2$ ) cells filled with Cl and Br gas (37); see Fig. 3. For transmission of Cl, see also (24, 36), of Br (49). Aqueous solutions of acetone ( $C_3H_6O$ ) (1), of *p*-nitrosodimethylaniline ( $C_8H_{10}N_2O$ ) (37, 45), etc., may assist in isolating the UV, especially when presence of radiation at  $\lambda > 0.5\mu$  can be ignored, as in usual photographic work. See also Fig. 4 and Special Filters, 4.





FIGS. 3, 4, 5.—Transmission of filters of Class 3.  
For description of filters, see Table 1.

much of IR, either with or without v, by filters of Class 1 (Fig. 1). For isolation of  $\lambda < 0.3\mu$ , see text for Class 3; of  $0.7\mu < \lambda < 1.5\mu$ , use W (or Gl) + D<sub>3</sub>, or W (or Gl) + G<sub>C4</sub> (or G<sub>N3</sub>) + a red glass, of  $1\mu < \lambda < 3\mu$ , use G<sub>14</sub> (or D<sub>2</sub>) + G<sub>1</sub> + G<sub>C7</sub>; of  $2\mu < \lambda < 3\mu$ , use G<sub>14</sub> (or D<sub>2</sub>) + G<sub>1</sub> + G<sub>C6</sub>. Certain regions (residual rays) between  $\lambda = 8\mu$  and  $\lambda = 152\mu$  may be isolated by multiple reflection from SiO<sub>2</sub> ( $\lambda = 8$  to  $9\mu$ ), TII ( $\lambda = 152\mu$ ), and other substances (3, 4, 46); (see also p. 261).

5. Isolation or Removal of Certain Lines from a Line Spectrum.—[See also (32).] In combination with the following, filters of Classes 1 and 2 may be used to absorb the UV and IR.

(a) *Hg-arc in SiO<sub>2</sub>*.— $\lambda = 0.578\mu$  is absorbed and  $\lambda = 0.546\mu$  is transmitted by filter X. The visible lines (0.578, 0.546, 0.436, 0.405 $\mu$ ) may be readily isolated from one another by glasses (19, 22), solutions (28, 48), or otherwise (15). Certain of the UV lines (0.365, 0.335, 0.313, 0.303, 0.254, etc.) may be more or less isolated by Cl (36), Cl-Br, Ag, G<sub>N1</sub>, and G<sub>N2</sub>. In the IR, the group between 1.0 and 1.8 $\mu$  (strongest at 1.014 and 1.129 $\mu$ ) may be isolated from the other lines and in part from one another (see 4, *supra*). There is radiation at 300 $\mu$  also.

(b) *Hydrogen Tube*.—For isolation of visible lines, see (22).

(c) *Helium Tube*.—For isolation of some of visible lines, see (22). In IR there is an intense line at 1.084 $\mu$  and a weak one at 2.026 $\mu$ . The yellow line is absorbed by X.

(d) *Bunsen Flame*.—Most of the energy is concentrated at 4.4 $\mu$  and may be isolated by a gelatin filter of type D<sub>3</sub> (12).

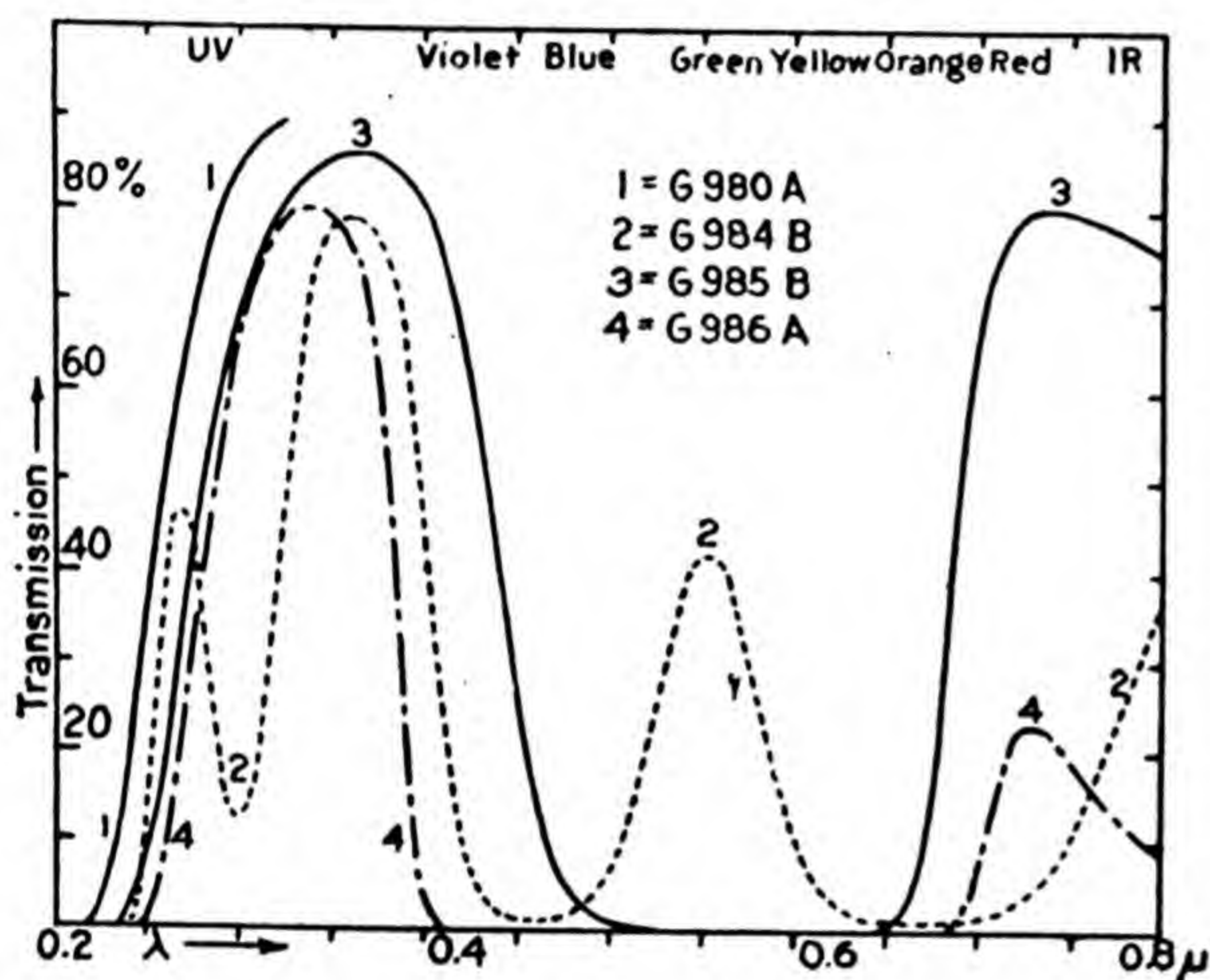
(e) *Flame Spectra*.—Sodium D-lines absorbed by X (16).

(f) *Copper Arcs*.—Blinding yellow glare absorbed by X (22).

*Classified References*.—Commercial filters, see (15, 16, 41, 44); discussion of special filters (6, 9, 10, 13, 14, 17, 19, 21, 22, 25, 28, 32, 34, 36, 37, 40, 47, 48, 49); germicidal action of UV (13); absorption data of special value in construction of filters, quantitative (1-6, 8, 9, 12-14, 17-24, 26, 27, 29, 30, 37-39, 42); qualitative (31, 33, 45).

TABLE 1.—FILTERS AND THEIR SYMBOLS

$\tau$  = thickness of absorber, unit = 1 mm. IR-limit [UV-limit] = wave-length bounding the transmission band on its



Special Filters

Filters, for isolating or for removing certain radiations emitted by the source being used, are especially convenient for the following purposes (see also Class 3, *supra*):

1. *Eye Protection*.—The cornea may be seriously injured by even a short exposure to UV at  $\lambda \geq 0.31\mu$ . When exposed to the quartz Hg-arc, unscreened metal arc or spark, or other source which is intense in this region, the eyes should be protected by a filter which absorbs completely all radiations of  $\lambda < 0.35\mu$ , such as G<sub>4</sub>, D<sub>1</sub>, etc. (Fig. 1). Radiations of greater  $\lambda$  do not damage the eye unless so intense as to cause discomfort. Glasses are available for reducing the brightness and for absorbing most of the IR (7, 11, 20) (see also 5f).

2. *Trichromatic Photometry*.—The three filters typified by G<sub>14</sub> (red), G<sub>C3</sub> (green), and G<sub>C4</sub> or G<sub>C4</sub> (blue) form a set which is usually satisfactory; see also (17).

3. *Elimination of Stray Light*.—In spectrophotometric work at  $\lambda < 0.5\mu$  or  $\lambda > 0.65\mu$ , stray light may introduce error (18). For work in blue and violet it may be eliminated by filters of type G<sub>C6</sub>, in red by G<sub>14</sub>, and in far red by G<sub>C4</sub> + G<sub>14</sub>, by D<sub>3</sub>, or by D<sub>2</sub>.

4. *Isolation of Certain Spectral Regions*.—Extra-focal methods assist in isolation in UV (10) and IR (43, 46). Some of UV can be isolated from all other radiation by G<sub>N1</sub>, G<sub>N2</sub>, or Ag; most of v by G<sub>6</sub> + C, see also (25); all of v and UV to  $\lambda = ca. 0.3\mu$  by C;



IR [UV] edge: All filters except Cl and S are represented in Fig. 6.

Symbol	Filter	Lit.	Fig.
Ag	Ag chemically deposited on SiO <sub>2</sub> ; $\tau$ of Ag = $7.9 \times 10^{-4}$ ; no IR is transmitted. ....	(22); cf. (38)	3
C	Aqueous (H <sub>2</sub> O) solution: 57.0 g CuSO <sub>4</sub> ·5H <sub>2</sub> O per l of solution; $\tau = 10.00$ ; transmits UV to about $\lambda = 0.3\mu$ ; for IR-limit, see (6).....	(17)	1
C-K	Two aqueous (H <sub>2</sub> O) solutions in different glass cells; 57.0 g CuSO <sub>4</sub> ·5H <sub>2</sub> O per l, and 72.0 g K <sub>2</sub> Cr <sub>2</sub> O <sub>7</sub> per l: $\tau = 10.0$ for each; transmits practically no IR, but cf. (6).....	(17)	3
Ca	Calcite (CaCO <sub>3</sub> ): transmission $\perp$ axis; $\tau = 6.1$ ; for IR-limit, see (35).....	(39)	1
Cl	Cl-gas in quartz (SiO <sub>2</sub> ) cell.....	(37)	3
Cl-Br	Cl-gas and Br-vapor in quartz (SiO <sub>2</sub> ) cells: combined transmission.....	(37)	3
D <sub>1</sub> , D <sub>2</sub> , D <sub>3</sub>	Dyed gelatin films: no data beyond $0.7\mu$ ; (most of curves G <sub>4</sub> to G <sub>14</sub> can be approximately duplicated by such films).....	(15); cf. (12)	1
EA	Ethyl alcohol (C <sub>2</sub> H <sub>5</sub> OH), chemically pure: $\tau = 10$ ; IR-limit approximately that of H <sub>2</sub> O (W, Fig. 2).....	(39)	1
F	Fluorite (CaF <sub>2</sub> ), colorless: $\tau = 10$ ; for UV-limit, see F <sub>1</sub> and F <sub>2</sub> , Fig. 1.....	(42)	2
F <sub>1</sub>	Fluorite (CaF <sub>2</sub> ), best quality, colorless: thin plates, value of $\tau$ is not stated; for IR-limit, see F, Fig. 2.....	(31)	1
F <sub>2</sub>	Fluorite (CaF <sub>2</sub> ): transmission by prism and lenses; value of $\tau$ is not stated; data from Schumann's map; for IR-limit, see F, Fig. 2.....	(31)	1
G'*	Cover-glass, special crown for UV transmission; $\tau$ is very small.....	(31)	1
G''*	Glass, special crown for UV transmission; $\tau = 1$ .....	(31, 44)	1
G'''*	Glass, special for UV transmission: $\tau = 0.39$ .....	(22)	1
G <sub>1</sub> *	Glass, common cover-glass; $\tau$ is very small.....	(31)	1
G <sub>2</sub> *	Glass: $\tau = 11.9$ ; for UV-limit, see (22).....	(9)	2
G <sub>3</sub> *	Glass, crown: $\tau = 1.68$ .....	(20, 22)	1
G <sub>4</sub> *	Glass, crown: $\tau = 2.18$ ; for UV-limit, see G <sub>1</sub> Fig. 1.....	(7, 11)	2
G <sub>5</sub> *	Glass: $\tau = 8.30$ .....	(22)	1
G <sub>6</sub> *	Glass: $\tau = 2.05$ .....	(20)	1
G <sub>7</sub> * to G <sub>14</sub> *	Glass, yellow, orange, or red: principal coloring agent is CdS or Se; $\tau = 0.88$ to $4.23$ .....	(15, 20, 22)	1
GC <sub>1</sub>	Glass; Co:† $\tau = 4.62$ .....	(16, 22)	3
GC <sub>2</sub>	Glass; Co:† $\tau = 3.13$ .....	(12)	5
GC <sub>3</sub>	Glass; Co† + Cu:† $\tau = 2.59$ .....	(16, 22)	3
GC <sub>4</sub>	Glass; Co† + Cu:† $\tau = 2.40$ .....	(12)	5
GC <sub>5</sub>	Glass; Co† + Cu:† $\tau = 2.99$ ; IR transmission is somewhat similar to that of GC <sub>6</sub> .....	(22)	3
GC <sub>7</sub>	Glass; Cu:† $\tau = 5.55$ .....	(16, 22)	3
GC <sub>7</sub>	Glass; Cu:† $\tau = 4.93$ .....	(12)	5
GC <sub>8</sub>	Glass; Cr† + Cu:† $\tau = 2.99$ ; IR transmission is somewhat similar to that of GC <sub>7</sub> and GC <sub>9</sub> .....	(16, 22)	3
GC <sub>9</sub>	Glass; Mn† + Cr:† $\tau = 2.46$ ; should be tested for possible violet transmission.....	(12, 16, 20)	3
GC <sub>9</sub>	Glass; Mn† + Cr:† $\tau = 2.46$ ; should be tested for possible violet transmission.....	(12)	5
GN <sub>1</sub>	Glass; Ni:† $\tau = 4.37$ ; no IR transmission.....	(16, 22)	3
GN <sub>2</sub>	Glass; Ni:† $\tau = 2.68$ ; no IR transmission (12).....	(16, 22)	3
GN <sub>3</sub>	Glass; Ni:† $\tau = 3.20$ .....	(16, 22)	3
GN <sub>4</sub>	Glass; Ni:† $\tau = 2.85$ .....	(12)	5
G 980 A†	Glass for UV transmission: $\tau = 5.0$ ; practically no absorption if $0.3\mu < \lambda < 0.8\mu$ .....	(19)	4
G 984 B†	Glass for UV transmission: $\tau = 5.3$ ; middle of the transmission band at $0.5\mu$ to $0.6\mu$ has greater $\lambda$ than that of GC <sub>6</sub> .....	(19)	4
G 985 B†	Glass for UV transmission: $\tau = 5.0$ .....	(19)	4
G 986 A†	Glass for UV transmission: $\tau = 5.0$ .....	(19)	4
Gl	Glycerol, chemically pure: $\tau = 10$ ; IR-limit approximately that of W, see (8, 38).....	(39)	1
M	Mica: $\tau = 0.01$ ; for IR-limit, see (3).....	(12)	1
Q <sub>1</sub>	Quartz (SiO <sub>2</sub> ), crystalline: $\tau = 0.2$ ; for IR-limit see Q <sub>2</sub> , Fig. 2.....	(21)	1
Q <sub>2</sub>	Quartz (SiO <sub>2</sub> ), crystalline: $\tau = 2.0$ ; no great difference between dextro, levo, transmission $\perp$ , or $\parallel$ to axis; for IR-limit, see Q <sub>1</sub> , Fig. 2.....	(21)	1

Symbol	Filter	Lit.	Fig.
Q <sub>1</sub>	Quartz (SiO <sub>2</sub> ), crystalline: $\tau = 4.77$ ; for UV-limit see Q <sub>1</sub> and Q <sub>2</sub> , Fig. 1.....	(9)	2
RS	Rock salt (NaCl): value of $\tau$ is not stated; for IR-limit, see RS <sub>1</sub> , Fig. 2.....	(21)	1
RS <sub>1</sub>	Rock salt (NaCl): $\tau = 10$ ; for UV-limit, see RS, Fig. 1.....	(42)	2
S	Sylvite (KCl): $\tau = 10$ ; strong, narrow absorption bands at $\lambda = 3.18\mu$ and $\lambda = 7.08\mu$ ; free transmission through visible and into UV....	(5, 42)	2
W	Water (H <sub>2</sub> O) in cell with thin quartz (SiO <sub>2</sub> ) windows: $\tau = 10$ ; for UV-limit, see W <sub>1</sub> , Fig. 1.....	(9)	2
W <sub>1</sub>	Water (H <sub>2</sub> O), distilled, in cell with fluorite (CaF <sub>2</sub> ) windows: long exposure; $\tau = 0.5$ ; for IR-limit, see W, Fig. 2.....	(31)	1
W <sub>2</sub>	Water (H <sub>2</sub> O), pure, in cell with quartz (SiO <sub>2</sub> ) windows; $\tau = 20(?)$ ; for IR-limit, see W, Fig. 2.....	(29, 31)	1
X	Glass (22, 38) or solution (45) containing "didymium" (mixture of Nd and Pr).....		6

\* So far as known, all white, yellow, orange, and red glasses have IR transmissions similar to those of G<sub>1</sub> and G<sub>2</sub> (Fig. 2), cf. Fig. 6. Those containing Fe-impurities have a broad, weak absorption band at  $\lambda = 1.1\mu$ , cf. (11, 12).

† Principal coloring material.

‡ Trade designation; made by Corning Glass Works, Corning, N. Y., U. S. A.

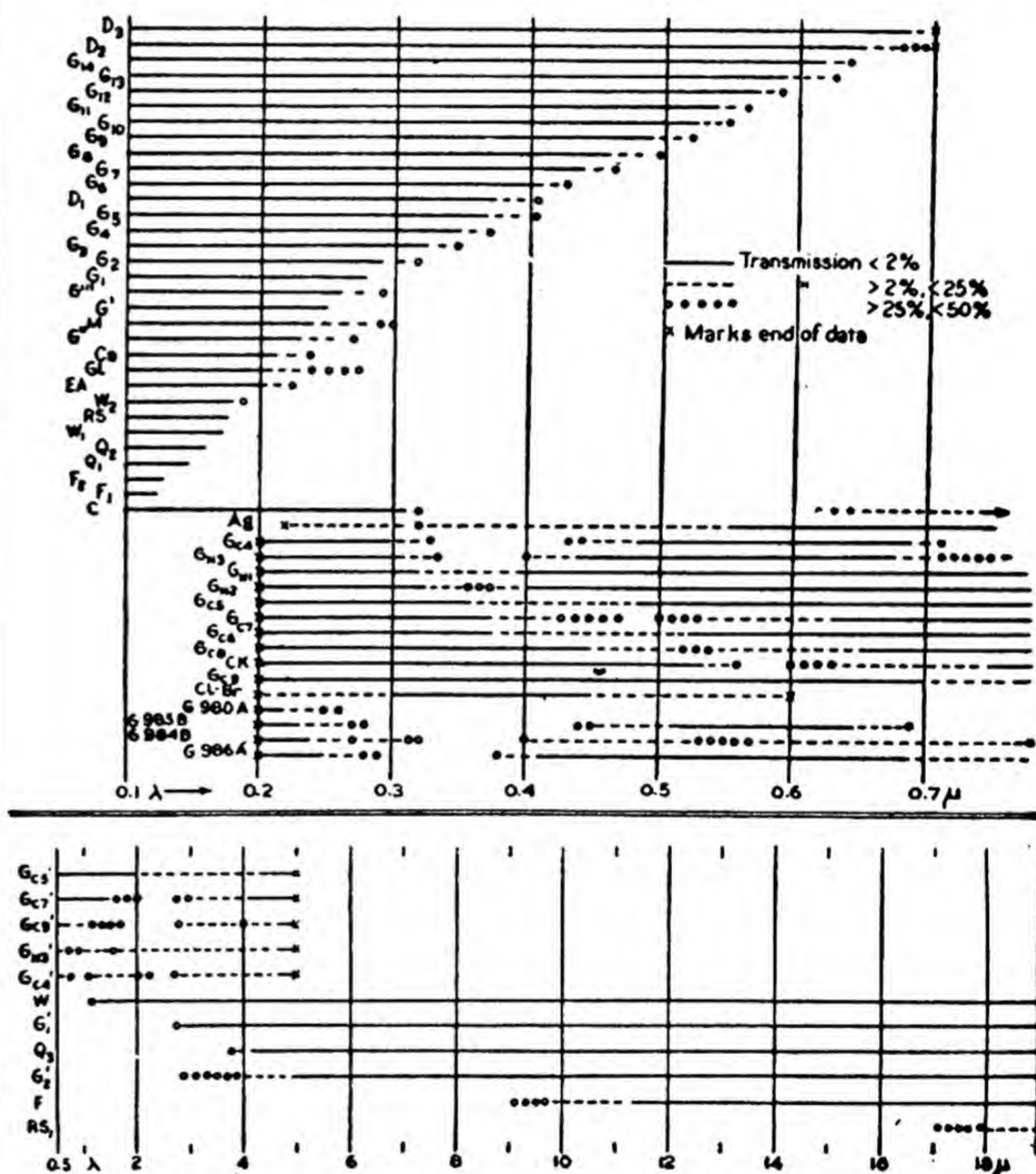


FIG. 6.—Filters of all classes: Regions of absorption and of transmission.

For more exact data, see Figs. 1 to 5; filters described in Table 1.

## LITERATURE

(For a key to the periodicals see end of volume)

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## SPECTROSCOPY

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## SPECTROSCOPIC STANDARDS OF WAVE-LENGTH

CH. FABRY

All wave-lengths ( $\lambda$ ) given below are expressed in international ångströms and are the wave-lengths in dry atmospheric air at 15°C and a pressure of one normal atmosphere. Some of them differ slightly from the corresponding values internationally accepted for use as secondary or tertiary standards. These differences are made necessary by the high precision of modern measurements and the very recent elimination of irregularities produced by the pole-effect (see p. 432). All arc lines refer to arcs in air at atmospheric pressure (not to arcs in a vacuum); those produced by arcs which are not satisfactorily defined are marked (\*).

## PRIMARY STANDARD

It is internationally agreed that in dry atmospheric air at 15°C and a pressure of one normal atmosphere the red line of cadmium,

produced under the conditions described by Michelson (1, 9) and specified below, has the wave-length (3)

$$\lambda_{Cd} = 6438.4696 \text{ Å} = 0.64384696 \mu$$

This defines the length of the international ångström and of the micron ( $\mu$ ) as used in the measurement of wave-lengths. As so defined,  $1 \text{ Å} = 10^{-10} \text{ m}$  and  $1 \mu = 0.001 \text{ mm}$  within the limits of experimental error.

The primary (cadmium) standard of wave-length shall be produced by high-voltage electric current in a vacuum-tube having internal electrodes and the form described by Michelson (11). The tube shall be maintained at a temperature not higher than 320°C, and shall have a volume not less than 25 cm<sup>3</sup>. The effective value of the exciting current shall not exceed 0.05 ampere. At room temperature the tube shall be non-luminous when connected to the usual high-voltage circuit.



Table 1.—Secondary Standards (2, 4, 5, 6, 7, 8, 10)

In arriving at the values here given, the papers mentioned have been critically compared. The table is divided into 3 sections: Fe-lines, Cu-, Ni-, and Si-lines that fill gaps occurring in the Fe-spectrum, and Ne-lines. Unit of  $\lambda = 1$  Int.  $\text{\AA} = 10^{-4}\mu = 10^{-8}$  cm.

## FE-LINES

As far as possible the values here tabulated refer to the Pfund arc (11) in air at atmospheric pressure. That arc satisfies the following conditions:

Anode is below and consists of a bead of iron oxide supported on a massive rod of iron or other good conductor of heat; cathode is above and consists of a rod of iron 6 or 7 mm in diameter, having close to its lower end a massive cooling cylinder of copper or brass. Current not over 5 amperes, 110 to 250 volts, arc 12 to 15 mm long; zone used is midway between the electrodes and not over 1.5 mm wide.

These values are the most accurate and are unmarked. Others, obtained with the arc between two rods of iron 6 to 7 mm in diameter, current about 6 amperes and no statement of either length of arc or of portion used, are marked (\*).

$\lambda_F$	$\lambda_F$	$\lambda_F$	$\lambda_F$
*2373.737	3977.744	4966.097	6393.606
*2413.310	4021.870	4994.132	6430.852
*2562.541	4074.789	5001.872	6494.985
*2588.016	4076.638	5012.072	6546.245
*2628.296	4095.973	5041.759	6592.920
*2679.065	4107.492	5049.825	6677.994
*2714.419	4118.549	5083.343	6703.573
*2739.550	4134.680	5110.414	6733.164
*2778.225	4147.673	5123.723	6750.157
*2813.290	4156.803	5150.843	6752.724
*2851.800	4175.639	5167.491	6806.851
*2874.176	4184.894	5192.353	6828.612
*2912.157	4191.436	5202.339	6841.355
*2941.347	4203.987	5216.277	6843.676
*2987.293	4219.364	5232.948	6855.179
*3030.152	4233.609	5250.650	6885.772
*3075.725	4245.260	5266.564	6916.709
*3125.661	4282.406	5270.361	6933.628
*3175.447	4315.087	5302.309	6945.211
*3225.790	4352.738	5324.187	6951.271
*3271.003	4375.933	5328.534	6978.857
*3323.739	4427.313	5341.026	6988.531
*3370.789	4466.556	5371.493	6999.912
*3399.337	4494.568	5405.779	7022.976
3445.153	4531.152	5434.527	7038.255
3485.343	4547.851	5455.613	7068.418
3513.821	4592.655	5497.520	7090.410
3556.882	4602.945	5506.783	7107.464
3558.518	4647.437	5569.626	7112.178
3606.682	4691.414	5586.763	7130.946
3640.392	4707.282	5615.652	7132.996
3676.314	4710.287	5658.825	7164.472
3677.630	4733.596	*5763.013	7181.222
3724.381	4736.782	6024.065	7187.341
3753.615	4741.533	6027.058	7207.422
3805.346	4772.818	6065.489	7219.690
3843.261	4789.654	6136.620	7223.670
3850.820	4859.749	6137.697	7239.896
3865.527	4878.219	6191.563	7284.843
3906.482	4903.318	6230.729	7288.764
3907.937	4919.001	6265.141	7293.073
3935.816	4924.776	6318.023	7307.938
3940.882	4939.691	6335.338	7311.103

## FE-LINES.—(Continued)

$\lambda_F$	$\lambda_F$	$\lambda_F$	$\lambda_F$
7320.694	7511.047	7710.397	8198.960
7386.394	7531.178	7748.282	8220.413
7389.423	7546.177	7780.594	8327.069
7401.691	7568.931	7832.233	8331.956
7411.184	7583.801	7937.172	8387.787
7418.676	7586.050	7945.882	8468.422
7443.031	7620.538	7998.980	8514.088
7445.778	7653.783	8028.356	8661.915
7491.678	7661.230	8046.084	8688.641
7495.092	7664.306	8085.207	8824.238
7507.300			

## CU-, NI- AND SI-LINES

(a) Copper: Arc between rods of Cu 4 mm in diameter, current = 4 to 5 amperes. (b) Silicon: Arc between ordinary rods of carbon; light from electrodes is eliminated. (c) Nickel: Arc between rods of Ni 5 mm in diameter, current = 6 amperes.

$\lambda_{Cu}$	$\lambda_{Cu}$	$\lambda_{Cu}$	$\lambda_{Si}$
*2112.105	*2242.622	*2369.891	*2528.516
*2126.047	*2276.261	$\lambda_{Ni}$	$\lambda_{Ni}$
*2189.631	*2303.134	*2435.159	*5857.759
*2218.107	*2334.816†	*2506.904	*5892.882

\* No statement of length of arc or of portion used. † A Sn-line.

## NE-LINES

The lines are emitted by a tube containing Ne at a pressure of a few mm of mercury.

$\lambda_{Ne}$	$\lambda_{Ne}$	$\lambda_{Ne}$	$\lambda_{Ne}$
5400.562	6096.163	6334.428	6717.043
5852.488	6143.062	6382.991	6929.466
5881.895	6163.594	6506.528	7032.412
5944.834	6217.280	6532.883	7173.938
5975.534	6266.495	6598.953	7245.165
6029.997	6304.789	6678.276	7535.785
6074.338			

Table 2.—Tertiary Standards (11)

All the following tertiary standards are Fe-lines emitted by a Pfund arc under the conditions stated in Table 1. Their wavelengths have been determined by interpolation from those of the secondary standards, and the published values have been corrected so as to make them accord with the values adopted for the secondary standards. Unit of  $\lambda = 1$  Int.  $\text{\AA} = 10^{-4}\mu = 10^{-8}$  cm.

$\lambda_F$	$\lambda_F$	$\lambda_F$	$\lambda_F$
3370.786	3485.343	3586.116	3659.521
3379.023	3489.674	3589.109	3669.524
3380.115	3495.290	3594.635	3676.314
3392.657	3497.111	3603.207	3677.630
3393.982	3497.844	3606.683	3679.917
3399.337	3506.501	3608.863	3684.113
3401.523	3513.821	3617.792	3687.460
3402.261	3521.265	3618.771	3690.732
3407.465	3529.820	3621.465	3695.055
3413.136	3541.087	3623.189	3702.035
3417.845	3542.080	3625.149	3704.464
3418.511	3545.642	3630.353	3705.569
3424.288	3556.882	3631.467	3707.051
3427.124	3558.518	3632.043	3711.227
3445.153	3565.382	3638.301	3715.916
3447.282	3576.761	3640.393	3719.936
3450.334	3581.196	3645.826	3722.566
3458.307	3582.202	3647.845	3724.381
3465.864	3584.664	3649.510	3727.623
3476.706	3585.322	3651.472	3732.400



Table 2.—(Continued)

$\lambda_F$	$\lambda_F$	$\lambda_F$	$\lambda_F$
3733.320	3841.052	3966.066	4154.501
3734.869	3843.261	3967.423	4156.803
3737.135	3846.805	3969.260	4170.904
3738.310	3849.971	3971.325	4175.639
3742.624	3850.821	3977.744	4177.596
3745.564	3852.577	3981.774	4181.758
3745.904	3856.373	3983.960	4184.894
3748.265	3859.914	3986.176	4191.436
3749.489	3865.527	3990.378	4202.030
3753.615	3867.220	3997.395	4203.987
3756.943	3871.752	4005.246	4213.649
3758.237	3872.505	4009.716	4216.185
3760.054	3873.764	4014.534	4219.364
3763.792	3878.022	4021.870	4226.423
3765.544	3878.575	4031.964	4233.609
3767.196	3883.286	4044.614	4245.260
3774.827	3884.362	4045.816	4250.789
3776.459	3886.286	4062.486	4266.968
3781.191	3887.051	4066.979	4267.830
3785.951	3888.518	4067.275	4271.764
3786.681	3895.658	4067.983	4282.406
3787.883	3899.709	4074.789	4285.447
3790.096	3902.950	4076.638	4294.128
3794.342	3903.902	4085.008	4298.041
3795.005	3906.483	4095.973	4305.455
3797.518	3907.937	4098.183	4307.907
3798.514	3910.847	4100.740	4315.087
3799.550	3917.185	4107.492	4325.764
3805.346	3920.260	4109.806	4327.099
3806.702	3922.914	4114.449	4337.050
3807.540	3925.945	4118.549	4346.559
3808.732	3927.921	4120.210	4351.550
3814.527	3930.299	4121.805	4352.738
3815.843	3932.631	4122.519	4358.505
3821.161	3935.816	4127.611	4367.583
3824.445	3937.331	4132.080	4369.776
3825.885	3940.883	4132.902	4375.933
3827.826	3942.443	4134.680	4383.549
3833.313	3948.778	4137.000	4387.898
3834.225	3952.605	4143.418	4390.955
3839.260	3956.459	4143.870	4404.753
3840.440	3956.680	4147.673	4407.715

Table 2.—(Continued)

$\lambda_F$	$\lambda_F$	$\lambda_F$
4408.419	4678.453	5166.286
4415.126	4691.414	5167.491
4422.572	4707.282	5168.901
4427.313	4710.287	5171.599
4430.620	4733.596	5192.353
4435.153	4736.782	5198.712
4442.345	4741.533	5202.339
4443.197	4745.805	5216.277
4447.723	4772.818	5227.189
4454.384	4786.809	5232.948
4459.122	4788.759	5242.492
4461.655	4789.655	5250.650
4466.556	4802.881	5266.564
4476.022	4859.749	5269.537
4489.742	4878.220	5270.361
4490.085	4903.318	5302.309
4494.568	4919.002	5307.361
4514.190	4924.776	5324.187
4517.528	4939.691	5328.534
4528.619	4966.099	5332.901
4531.152	4994.132	5341.026
4547.851	5001.872	5371.497
4587.134	5012.072	5397.132
4592.655	5041.074	5405.779
4602.006	5041.759	5429.700
4602.945	5049.825	5434.527
4619.296	5051.637	5446.920
4630.126	5083.343	5455.613
4632.915	5098.704	5497.520
4638.017	5110.414	5501.469
4647.437	5123.723	5506.783
4654.502	5127.364	6027.058
4667.458	5150.843	6065.489
4673.168	5151.914	

## LITERATURE

(For a key to the periodicals see end of volume)

- (<sup>1</sup>) Babcock, 538, 2: 40; 25. (<sup>2</sup>) Babcock, 51, 66: 256; 27. (<sup>3</sup>) Benott, Fabry and Perot, 238, 15: 1913. (<sup>4</sup>) Buisson and Fabry, 51, 7: 169; 08. (<sup>5</sup>) Burns, 48, 11: 301; 25. (<sup>6</sup>) Kayser, *Trans. International Union for Co-operation in Solar Research*, 3: 30, 139; 11. (<sup>7</sup>) Meggers and Kiess, 51A, 19: 273; 24. (<sup>8</sup>) Meggers, Kiess and Burns, 51A, 19: 263; 24. (<sup>9</sup>) Michelson, 238, 11: 1895. (<sup>10</sup>) Mitra, 18, 19: 315; 23. (<sup>11</sup>) St. John, 538, 1: 35; 22.

## EMISSION SPECTRA OF ELEMENTARY SUBSTANCES

## H. KAYSER

In the following table are given the wave-lengths ( $\lambda$ ) of selected lines from the spectra of air, of all known elements except Ac, Ma, Pa, Po, Re, UX<sub>2</sub>, and certain doubtful, or unidentified elements. The number of lines given in each case is determined by the spectroscopic importance of the element and by the number of lines which its spectrum contains; the strongest and the most easily reversed lines throughout the spectrum have been given, and the distribution of the lines has been chosen so that the list will satisfy the practical requirements of such a table and will exhibit all the characteristics of the spectrum. In the spark-spectrum of air all the observed lines are given, although many of them are false, being metallic lines. For each element, are given the more important literature references from which the data were taken; for a more complete list of references, see Kayser, *Handbuch der Spektroskopie*, Vols. 5 to 7, or Watts, *Index of Spectra*. It is assumed that the wave-length of a line is the same in the arc as in

the spark, that changes in  $\lambda$  arise only from pressure, magnetic and electric fields, pole-effect, and apparent shifts from unsymmetrical broadening. The data given refer to atmospheric pressure, except in those cases in which the observation must be made under reduced pressure. The precision of measurements in the infra-red is so low that the correction from the Rowland to the international scale is unimportant; in all other cases  $\lambda$  is expressed in international Angstroms.

The values given for  $\lambda$  are weighted means of the best determinations available, and consequently are to some extent arbitrary. The relative intensities of the lines depend upon so many conditions, frequently undefined or even undefinable, that an average is meaningless. But the intensity of a line is an important characteristic of it, and in very many cases the relative intensities vary from one type of spectrum—arc, spark, Geissler tube—to another much more than they vary with the conditions in any one



type; for this reason a kind of average, or typical value of the relative intensity is given.

Spectra obtained by means of the arc, spark, or Geissler tube are generally mixtures of different spectra. Some of the lines belong to the neutral atom (denoted by A or AI), some to the simply ionized atom ( $A^+$  or AII), some to the doubly ionized atom—the atom which has lost two electrons—( $A^{++}$  or AIII), etc. It is now possible to determine in many cases the particular type of atom to which a given line belongs. In such cases, the type is indicated in the following table by placing before the wave-length the proper symbol (I, II, III . . . ).

#### WAVE-LENGTHS ( $\lambda$ ) OF SELECTED LINES IN EMISSION SPECTRA OF AIR AND OF ELEMENTARY SUBSTANCES

There are no data for Ac, Ma, Pa, Po, Re, and UX<sub>2</sub>. For basis of selection of lines given, etc., see preceding text. Uncertainty in  $\lambda$  is not over 3 units in the last figure. Numbers in the columns A, S, and G indicate the relative intensities of the lines in the arc, spark and Geissler-tube spectrum, respectively; in each case 1 generally denotes the weakest and 10 the strongest line, but very weak lines may be marked 0, and very strong ones 15, 20, 25, or 30. I, II, III . . . indicate that the line is emitted by the neutral, the simply ionized, the doubly ionized . . . atom; R = easily reversed, u = unsharp, broad; U = very unsharp, very broad; r [v] = unsymmetrically broadened, the excess broadening is on the red [violet] side, i.e., towards the longer [shorter] wave-lengths; the number of components of an unresolved multiple line is indicated by the letters d, tr, qr, qn, s; where d = 2, tr = 3, qr = 4, qn = 5, s = 6.

Unit of  $\lambda = 1 \text{ \AA} = 0.1 \text{ m}\mu = 10^{-4} \mu = 10^{-8} \text{ cm.}$

Air (3, 74, 75, 91, 101, 102, 128, 136, 198, 199, 255, 259, 274)

$\lambda$	S	E*
8 719.2	0	N
12.0	0	N
03.8	0	N
8 692	0	
86.4	0	N
83.7	1	N
80.6	2	N
30.0	0	
8 594	0	
8 446.8	5	O
8 242.8	4	N
30.2	0	O
23.5	4	N
16.7	7	N
11.1	2	N
00.7	1	N
8 188.4	4	N
85.3	4	N
7 952.3	2	O
51.1	3	O
47.8	4	O
7 775.6	6	O
74.3	7	O
72.1	10	O
7 635.7	1	A
7 515.2	0	A
05.8	6	A
7 479	0	O
68.7	10	N
56.7	0	

Air.—(Continued)

$\lambda$	S	E*
7 442.7	10	N
32.9	0	
24.0	8	N
7 384.5	1	A
7 157.4	9	O(?)
7 067.6	0	A
6 965.9	1	A
50	0U	
6 887.6	1	
64	0	
11.9	0	
6 721.3	1	
6 654.8	2	
40.7	0	
10.4	6	N
6 563.2	3	H
6 482.0	5	N
56	0	O
6 379.3	2	N
70.7	0	
58.1	0	N
41.5	0	N
6 284.3	1	N
6 171.0	2	O
58.1	0	O
5 952.4	4	N
41.6	10	N
40.5	1	N
31.8	7	N
27.8	4	N
5 767.4	2	N

Air.—(Continued)

$\lambda$	S	E*
5 747.5	1	N
30.6	2	N
10.7	2	N
5 686.2	3	N
79.5	10	N
75.9	3	N
66.6	5	N
45.6	1	N
5 592.3	0	O
66	0	N
52.0	2	N
43.4	3	N
35.2	5	N
30.2	3	N
26.2	2	N
5 495.7	2	N
80.1	1	N
78.1	0	N
62.8	1	N
54.1	1	N
52.1	1	N
32.1	0	N(?)
11.5	1	N
5 356.4	0	N
51.2	0	N
41.2	1	N
38.7	1	N
28.6	0	N
25.1	0	O
20.5	1	N
5 281.7	0	N
63	0	
50.6	1	N(?)
06.5	1	O
5 190.6	1	N
85.1	0	N
83.2	0	O
79.4	1	N
75.9	2	N
73.4	1	N
72	1	N
60.1	0	O
50	0	
43.6	0	O
36	0	
5 073.5	0	N
61.8	0	N
45.1	2	N
32	0	
25.7	2	N
22.9	1	N
16.4	2	N
13.9	0	
10.0	2	N
07.4	3	N
05.2	6	N
01.4	6	N
4 994.4	3	N
91.3	1	N
87.4	1	N
64.7	0	N
55	1	O
43.0	1	O

Air.—(Continued)

$\lambda$	S	E*
4 942.5	1	N
41.0	1	N
34.8	1	N
24.6	2	O
06.8	1	O
4 895.3	1	N
90.9	0	O
79.7	1	N
71.6	0	O
60.3	1	N
56.8	1	O
47.7	1	N(?)
10.3	2	N
05.9	1	N
03.3	5	N
4 793.7	2	N
88.2	4	N
81.2	0	N(?)
79.8	2	N
74.2	1	N
64.6	1	N
51.2	1	O
35.7	1	N
18.4	2	N
09.9	2	O
05.4	3	O
05.1	1	N
03.1	0	O
4 699.2	3	O
97.6	0	N(?)
76.2	3	O
74.9	1	N
61.6	5	O
54.5	1	N
50.8	2	O
49.1	4	O
43.1	4	N
41.8	3	O
40.5	1	N
38.8	2	O
34.0	1	N
30.53	10	N
21.39	4	N
13.84	3	N
09.4	1	N
07.14	4	N
01.48	4	N
4 596.12	3	O
90.93	3	O
52.5	2	N
44.8	1	N
29.9	2	N
14.8	2	N
07.62	2	N
4 477.7	1	N
69.4	1	O
67.8	2	O
65.4	2	O
60.1	1	N
52.4	2	O
47.04	6	N
43.3	1	O
34.0	0	N

\* Symbol of elementary substance to which the line is due.



## INTERNATIONAL CRITICAL TABLES

Air.—(Continued)			Air.—(Continued)			Air.—(Continued)			A.—(Continued)		
$\lambda$	S	E*	$\lambda$	S	E*	$\lambda$	S	E*	$\lambda$	Rd†	Bl†
4 432.4	2	N	4 069.90	8	O	3 331.8	2	N	I 7 503.868	4	
30.1	1	N	63.2	1	N	29.5	2	N	7 435.5	1	
25.9	1	N	57.8	1	N	25	1	O	I 7 383.979	5	
17.0	5	O	41.3	3	N	20.7	2	O	72.119	1	
14.9	6	O	34.9	2	N	18.8	1		53.316	1	
01.2	1	N	25.7	1	N	12.5	1	O	15.9	1	
4 396.0	1	O	14.0	1	O	01.9	1		11.6	1	
92.4	0	N(?)	3 995.1	10	N	3 288.9	1		I 7 272.935	3	
79.6	1	N	82.76	2	O	65.2	1	O	06.986	1	
71.4	1	N	73.30	4	O	3 158.7	1		I 7 147.042	1	
69.2	1	O	68.4	1	A(?)	39.3	2	O	I 7 067.217	5	
66.87	3	O	55.9	4	N	35.3	1	O	30.250	2	
61.6	0	N	54.4	1	O	30.1	1		I 6 965.430	6	
51.3	2	O	47.45	1	O	3 059.15	2		37.666	2	
49.40	4	O	45.1	1	O	47.0	1		6 888.8	1	
48.0	2	N	40.2	1	N	07	1	O	71.290	4	
47.44	2	O	33.6	0	?	2 927.5	1		6 786.3	1	
45.54	3	O	19.10	6	N	2 858.3	1		56.4	1	
36.8	2	O	12.1	3	O	2 795.5	1		52.831	5	
31.9	1	O	09.1	1	N	55.9	2		19.2	2	
31.04	1	N	07.6	1	O	49	1		6 698.9	3	
28.5	1	O	3 893.3	1	N	46.7	1		84.4	1	
27.5	1	O	82.3	2	O	39.8	1		I 77.282	5	
25.7	1	O	64.6	1	O	2 599.5	2		64.1	3	
19.62	3	O	56.7	1	N	14.5	1		60.7	3	
17.11	3	O	51.2	1	O	07.2	2		40.2		0
03.7	1	O	50.6	1	N	2 445.5	1	O	04.9	3	
4 275.9	1	N	48.04	1	O	33.6	1	O	6 513.7	1	
66.4	2	N	45.1	0	N	06.9	1		6 493.9	2	
53.7	2	O	42.8	1	N	04.9	2		81.0	2	
41.75	2	N	39.1	2	N	2 399.4	1		66.5	3	
36.8	3	N	30.7	1	N	95.62	1		31.6	3	
28	2	N	04.0	1	O	82.1	2		16.307	6	
23.3	1	N	3 770.9	1	N	18.5	1	O	6 384.5	4	
11.1	1	N	59.8	1	O	2 287.9	1	N	69.6	3	
06.7	2	N	54.5	1	O				64.8	3	
4 199.3	0	N	49.51	5	O				07.6	3	
89.8	6	O	29.3	1	N				6 296.8	3	
85.5	4	O	27.34	4	O				78.6	2	
76.2	2	N	12.7	2	O				48.5	3	
69.36	1	O	09.2	1	O				43.4		2
53.5	3	O	07.3	1	O				15.9	4	
45.90	3	N	02.9	1					12.4	4	
43.7	1	O	3 639.6	3					6 172.9	4	
42.2	1	O	09.8	1					72.2		4
33.70	2	N	3 594.6	1					70.1	3	
32.88	2	O	89.0	1					65.1	3	
29.5	1	O	77.2	1					55.1	3	
24.1	2	O	70.3	1					45.4	4	
21.5	2	O	60.6	1					27.4	3	
20.5	2	O	14.8	1					21.7	2	
19.3	4	O	3 491.9	2					19.5	2	
14.0	0	O	71.2	2					14.8		3
12.09	1	O	50.9	1					13.4	2	
10.84	2	O	37.32	3	N				05.8	4	
05.00	3	O	08.3	2	O				04.5	2	
03.3	2	N	3 390.3	2	O				01.1	2	
4 097.2	3	N	77.2	2	O				6 098.7	4	
93.00	2	O	74.0	2	N				90.8	3	
89.1	1	O	70.9	1	N				67.7	1	
85.20	2	O	67.3	1	N				64.7	3	
78.9	2	O	65.8	1	N				59.4	5	
75.93	8	O	54.08	1	O						
72.25	8	O	44.8	1							

A (83, 129, 162, 175, 181, 184, 202, 237)		
$\lambda$	Rd†	Bl†
13 719	4	
13 505	4	
12 500	30	
I 11 590	8	
I 10 640	12	
I 9 658.9	7	
I 9 225.9	5	
I 9 123.7	10	
I 8 521.442	5	
I 8 424.648	10	
I 08.213	6	
05	6	
I 8 264.523	5	
I 8 115.308	10	
I 03.692	3	
I 8 014.785	3	
I 06.157	8	
I 7 948.176	5	
I 7 724.210		
I 23.759	5	
I 7 635.106	6	
I 7 514.650	4	

† Rd [Bl] = intensity of the line in the red [blue] spectrum.



A.—(Continued)			A.—(Continued)			A.—(Continued)			A.—(Continued)		
$\lambda$	Rd†	Bl†	$\lambda$	Rd†	Bl†	$\lambda$	Rd†	Bl†	$\lambda$	Rd†	Bl†
6 052.6	4		5 152.5	3		I 4 333.561	7		3 932.56		5
43.2	6		45.40		4	32.04		3	31.20		3
32.127	6		42.0		4	31.17		7	28.61		8
25.4	3		5 063.0	1		09.15		2	25.76		4
13.6	3		62.1		6	00.66		2	14.78		5
05.8	2		60.2	3		I 00.101	8		11.56		3
5 999.2	2		54.3	1		4 282.88		4	07.70		3
87.3	3		49	2		77.5		8	I 3 899.90	2	
71.7	3		24.3		1	I 72.169	8		I 94.64	3	
68.4	2		17.2		5	66.4		6	91.99		6
64.5	2		09.3		6	66.286	8	6	91.39		4
49.3	3		4 972.2		3	59.362	9		80.29		3
43.0	3		65.1		4	I 51.184	5		75.25		5
40.9	2		55.1		2	37.21		4	72.14		4
28.5	4		42.9		2	28.2		7	68.55		7
27.1	2		33.2		4	26.98		3	I 66.14	1	
16.6	2		04.8		2	22.64		4	50.56		9
12.1	5		4 894.8	1		18.66		3	45.37		3
00.5	1		88.7		2	03.4		2	I 34.65	5	
5 888.7	4		88.1	1		01.9	2		30.43		3
82.7	3		82.3		2	I 00.678	9		26.80		4
60.4	3		79.9		6	I 4 198.316	8		09.46		4
32.1	1		67.5		4	I 91.027	8		08.58		2
02.2	1		65.9		4	I 90.714	5		03.23		3
5 772.3	2		47.77		6	I 81.884	7		3 799.47		3
39.7	3		05.99		8	79.30		3	95.38		5
5 691.7	1		4 768.4	1		78.38		3	86.42		4
82.4	2		64.85		4	I 64.180	7		I 81.33	3	
59.2	3		35.87		5	I 58.591	9		80.89		7
50.8	5		26.83		4	56.14		4	I 75.4	1	
48.8	2		02.317	4		52.7	3		70.61		3
18.1	2		4 657.88		4	31.78		6	70.4	3	
07.0	6		37.17		3	28.6		3	66.14		3
5 597.7	2		I 28.445	5		12.82		3	65.32		6
81.6	2		09.56		6	03.95		9	63.59		4
72.6	4		4 596.096	5		4 099.45		2	53.5		3
59.7	2		89.89		6	82.41		4	37.92		5
58.8	5		79.35		6	80.61		2	29.33		9
25.1	2		47.7		2	79.61		4	24.53		3
06.4	2		45.06		6	77.03		2	20.46		3
5 495.9	6		I 22.325	4		76.70		6	18.25		5
73.6	2		I 10.733	8		72.43		4	17.21		3
67.2	2		02.95		3	72.02		7	I 3 696.5	1	
57.8	2		01.5	1		I 54.50	3		I 90.9	1	
51.7	5		4 498.5		2	52.96		4	80.1	4	
43.3	2		91.0		2	45.88	4		78.31	5	
42.1	1		88.2		2	I 44.419	8		70.7	3	
40.1	2		81.83		5	42.89		6	60.52		3
21.6	4		33.90		2	38.83		4	59.5	2	
10.6	2		31.00		4	35.45		3	56.12		2
5 373.6	2		30.18		4	33.85		3	55.35		4
05.8		6	25.99		8	I 32.96	2		50.9		3
5 287.0		3	01.00		5	13.84		7	I 49.9	3	
54.4	2		00.09		4	3 992.03		4	I 43.1	2	
52.9	3		4 379.64		6	79.40		5	39.86		4
21.6	3		71.31		5	74.52		4	37.86		4
17.0		2	70.75		5	68.37		4	37.08		3
5 188.3	3		I 63.78	3		60.45		3	I 34.46	4	
87.3	3		62.04		3	58.40		3	I 32.65	4	
77.6	1		52.21		4	I 48.980	7		22.18		4
76.4		3	48.0		10	I 47.55	4		I 06.53	5	
65.8		4	I 45.168	7		46.10		4	I 3 599.3	1	
62.4	4		I 35.29	6		44.30		5	88.49		9



A.—(Continued)			A.—(Continued)			A.—(Continued)			Ag.—(Continued)		
$\lambda$	Rd†	Bl†	$\lambda$	Rd†	Bl†	$\lambda$	Rd†	l† B	$\lambda$	A	
3 582.39		6	3 204.35		3	2 234.6		4	4 677.9	2u	
81.66		5	3 181.09		4	19.8		4	I 68.54	8r	
76.65		8	69.71		5	2 050.4		1	15.9	3U	
I 72.27	2		61.44		5	1 886.1		7	4 556	3U	
I 67.68	4		39.06		5	79.7		8	I 4 476.06	6	
65.06		3	3 093.40		6	77.7		8	47.0		
I 64.41		2	34.6	3		73.2		10	4 396	2u	
I 64.3	2		33.6		3	68.7		8	85		
I 63.2	3		29.0		4	65.9		8	79.24	2u	
61.06		6	21.8	3		55.7		9	11.05	2r	
I 59.54		7	2 979.1		6	43.1		9	I 4 212.01	8R	
56.0	2		68.3	2		36.3		9	4 085.9		
55.31	2		67.2	5		31.4		9	I 55.25	8R	
I 54.31	4		55.4		5	30.6		10	3 985		
48.53		3	43.0		7	20.0		7	I 81.63	4r	
45.86		7	31.5		2	1 788.1		5	49.4	1	
45.64		7	24.7		3	1 675.6		7	I 3 840.79	2	
35.37		5	2 896.8		2	73.5		7	10.7	2u	
21.97		2	91.7		4	69.7		7	3 710	1	
21.29		3	84.1		4	00.7		5	I 3 682.3	2u	
20.02		4	78.8		3	1 589.5		4	24.2	1u	
14.40		6	73.4	3		1 460.1		5	16		
11.16		5	65.9		4	1 335.8		7	3 542.5	3	
09.80		4	55.2		3	34.5		7	20	1	
09.36		2	42.6		2	33.7		5	07	1	
03.59		2	33.5	3					05.1		
3 499.68		3	06.2		6				01.8	3	
91.57		8	02.1	3					3 475.8		
91.29		5	2 796.7		2				69.2	1	
80.51		5	69.6		6				56	1	
78.26		4	62.0		3				13	1	
76.79		7	53.8		8				09	1	
66.3		3	44.8		8				I 3 382.88	10R	9R
64.20		4	32.6		6				64		1
I 61.06	3		08.3		8				52		1
54.15		3	2 647.5		8				49	1	
30.48		2	14.5	4					31.8		2
29.69		2	2 562.2		6				12.6		1
21.67		3	44.7		6				05.7	2	
I 3 393.8	3		16.7		8				01.5		2
92.8	2		16.2	4					3 299.4		2
91.77		5	15.5		8				89.2		2
88.54		5	12.2		3				80.67	10R	9R
76.47		4	00.3		4				67.33		1
73.5	2		2 499.4		4				52.8		1
70.93		2	90.9		6				49.8		1
66.61		2	80.8		5				44.97		3
58.51		4	79.1		6				41.3		1
50.97		4	52.9		1				33	3u	1
44.73		4	38.7		6				23		2
36.15		4	15.6		6				16.7		1
25.49	2		04.3		4				15.6	2	1
I 19.30	2		2 395.6		4				07.3		1
11.19		5	64.1		4				00.0		1
07.23		4	50.5		4				3 191.8		1
01.81		6	44.3		5				87.8		1
3 295.3	2		37.7		5				85.1		1
93.65		4	31.6		4				80.7		2
85.77		7	16.4		4				73.6		1
81.71		5	13.9		4				72.3		1
63.58		3	09.3		4				70.6	2	1
49.83		3	2 281.5		5				53.1		2
43.72		3	52.3		4				30.0	3	1
12.62		2	43.6		4				17.8		1

A.—(Continued)		
$\lambda$	Rd†	l† B
2 234.6		4
19.8		4
2 050.4		1
1 886.1		7
79.7		8
77.7		8
73.2		10
68.7		8
65.9		8
55.7		9
43.1		9
36.3		9
31.4		9
30.6		10
20.0		7
1 788.1		5
1 675.6		7
73.5		7
69.7		7
00.7		5
1 589.5		4
1 460.1		5
1 335.8		7
34.5		7
33.7		5

Aldebaranum, see Yb

Ag (24, 59, 78, 90, 91, 101, 111, 123, 128, 181, 205, 214, 223, 274, 276)		
$\lambda$	A	S
39 951	8	
889	5	
I 18 382	1	
I 307	1	
I 17 415	1	
I 16 819	3	
I 12 551	1	
I 8 273.58	10	
I 7 687.85	10	
6 037		2
5 970		1
5 666.4	4u	2u
5 590		1u
70		1U
58		1U
45.65	4r	
29.9	2	
23.7	3	
5 494		1U
89		3U
I 71.51	6	5
I 65.43	10	6
03		1U
01		1U
5 333.3	2r	
29.7	4r	
5 276.4	1r	
I 09.04	10R	8
4 888.3	2u	
74.16	2r	1
48.1	2U	

Ag.—(Continued)		
$\lambda$	A	
4 677.9	2u	
I 68.54	8r	
15.9	3U	
4 556	3U	
I 4 476.06	6	
47.0		
4 396	2u	
85		
79.24	2u	
11.05	2r	
I 4 212.01	8R	
4 085.9		
I 55.25	8R	
3 985		
I 81.63	4r	
49.4	1	
I 3 840.79	2	
10.7	2u	
3 710	1	
I 3 682.3	2u	
24.2	1u	
16		
3 542.5	3	
20	1	
07	1	
05.1		
01.8	3	
3 475.8		
69.2	1	
56	1	
13	1	
09	1	
I 3 382.88	10R	9R
64		1
52		1
49	1	
31.8		2
12.6		1
05.7	2	
01.5		2
3 299.4		2
89.2		2
80.67	10R	9R
67.33		1
52.8		1
49.8		1
44.97		3
41.3		1
33	3u	1
23		2
16.7		1
15.6	2	1
07.3		1
00.0		1
3 191.8		1
87.8		1
85.1		1
80.7		2
73.6		1
72.3		1
70.6	2	1
53.1		2
30.0	3	1
17.8		1



Ag.—(Continued)			Ag.—(Continued)			Al (13, 32, 34, 59, 60, 62, 74, 75, 78, 90, 91, 106, 111, 163, 205, 210, 276)			Al.—(Continued)		
$\lambda$	A	S	$\lambda$	A	S	$\lambda$	A	S	$\lambda$	A	S
3 115		1	2 357.92		6				I 2 575.112	10R	6R
3 099.11	2	1	31.35	4	6				II 67.996	10R	6R
12.9		1	25.1		4	I 39 108			II 45.60		6
2 983.52		1	24.63	2	6	I 21 166			I 2 378.43	3	1
38.5	4	4	21.52		3	I 21 098			I 73.36	2R	2R
34.2		6	20.24	2	6	I 16 752			I 73.13	8R	4R
29.3		5	17.03	2	5	I 20			I 72.06	3	3
20.0		3	12.4	4U	2	I 13 151			II 69.30	1	4
I 02.08		4	09.54	6R	4	I 25			I 67.06	8R	4R
2 896.46		4	2 279.97	1	5	I 11 255			II 21.56	2	6
73.59	2	4	77.38		2	I 8 774.5	5r		I 12.4		1
24.40	6	1	75.24		2	I 7 836.9	6r		I 2 269.21	2R	
15.6		4	53.46		2	7 466			I 69.09	4R	2R
2 799.64		6	48.73	3	3	7 362.5	2r		I 63.73	2	
86.5		3	46.38	3	3	I 6 698.73	3		I 63.45	4R	2R
67.5		8	40.42		2	I 96.07	3		I 58.0	2	
56.4		6	38.36		2	II 6 243.347		10	I 10.05	2R	
43.9		3	29.51	2	4	II 31.759		7	I 04.63	2R	
21.79	3	2	26.12		2	6 176	1u		I 2 199.57	1	
12.1		4	19.70		2	51.7	1u		I 74.02	1R	1
2 688.4		3	11.18		2	II 5 861.53		7	I 68.00	1R	1
81.4		4	08.4	1	1	III 5 722.65		6	II 2 094.8		5
60.4	3	5	05.9	1	2	III 5 696.45		5	II 16.1		1
56.8		6	02.1	2	2	II 5 593.23		10	II 1 989.8		8
28.6		2	2 192	1	1	I 57.95	2		III 35.2		7
14.5		6	86.76	2	3	I 57.05	2		II 30.3		2
06.14		6	71.7		1	III 5 163.90		7	III 1 862.90		10
2 595.6		3	70.9		1	III 50.86		5	II 62.48		10
80.7		6	66.5	2	2	I 05	d		II 58.15		7
75.5	4U	1u	62.0		2	III 4 701.65		6	III 54.67		10
67.15		2	45.6	1	3	II 4 663.054		10	18.3		2
64.42		3	25.4		1	II 4 585.820		6	1 792		3
53.41		2	20.4	1	2	III 29.176		6	77		4
35.3		5	13.8	2	3	III 12.534		5u	II 67.6		9
06.65	2	5	2 070.0		1	III 4 479.968		5u	II 65.7		7
04.07		4	65.9		4	II 4 226.812		6	II 63.9	10d	
2 486.7		2	61		1	I 3 961.537	10R	8R	II 61.9		7
85.78		2	33.8		4	I 44.025	10R	8R	II 60.1		7
80.42		4	00.6		3	II 00.68		2	52		3
77.30		6	1 999.5		2	III 3 713.10		3u	II 50		2
73.88		7	56.9		3	III 02.09		2u	II 25		10
72.94		2	32.3		2	II 3 655.00		8d	II 21		9
62.27		4	16.3		4	III 12.35		7u	II 19		9
60.32		5	1 889		4	III 01.62		7u	II 1 671		10
53.37		6	80		4	II 3 587.06		10u tr	III 12		8
47.91	2	7	73		4	II 3 443.65		6	III 06		8
44.20		4	60		4	I 3 092.85	5R	4R	III 1 384		5
37.77	3	8	39		3	I 92.718	10R	8R	19?		6
29.65		7	16		3	I 82.162	10R	8R	10?		6
20.12		5	02		4	66.16	4	2	II 1 211.93		1
13.22	4	8	1 794		4	64.31	4	2	II 1 191.83		2
11.38		7	72		4	59.93	2	1	II 1 190.07		2
02.57		3	69		4	II 57.15	4	10	III 856.80		3
2 395.66		2	51		6	54.70	4	2	III 854.98		3
92.97		2	22		3	II 50.08	4	8	III 696.23		2
90.57		3	1 693		6	III 2 907.5		10	III 695.82		3
86.8		2	74		2	II 2 816.3		10u			
86.32		3	56.8		5	III 2 762.81		9			
83.20		2	1 566		6	II 2 669.17		10			
75.0	4U	3	39		4	I 60.394	10R	5R			
63.99		4	1 496		4	I 52.484	10R	4R			
62.19		3	86		4	II 31.73		7u			
58.85		5	45		5	I 2 575.44	3R	2			

As (13, 23, 59, 90, 91, 118, 136, 154, 200)

$\lambda$	A	S	G
6 170		6	
10		6	



As.—(Continued)				As.—(Continued)				As.—(Continued)				Au.—(Continued)			
$\lambda$	A	S	G	$\lambda$	A	S	G	$\lambda$	A	S	G	$\lambda$	A	S	G
6 023		6		4 065.4		2	7	1 001		10		2 963.77	2	1	
5 837.9			6	62.6			7	984		10		54.4		4	
5 731.8		1	6	37.0		6	6	63		10		32.19	5	4	
5 684.8		1	7	06.2		3	6	56		8		13.5	4	10	
57.0		1	8	3 948.6		3	6	52		8		07.1		4	
51.3	10	10		31.1		2	7	26		8		05.90	6	3	
20.6	1	10		22.5		10	7	878		8		I 2 891.95	4	2	
5 558.1	10	8		3 842.9		4	7	73		8		I 83.45	4	3	
5 497.8	10	7		3 787.2		3	6	27		5		38.0		3	
96.9	5	6		3 671.7			6	529		1		25.4		4	
5 331.3	8	7		3 551.6			5					22.7		3	
5 205.3	1	6		13.0			6					19.98		8	
5 182.2		7		3 255		2	6					02.21		10	
61.1	7	7		3 180.6			6					2 780.83		3	
07.6	8	8		26.9			6					I 48.26	6R	4	
05.5	8	8		I 19.6	4	7	5					I 00.88	4	3	
4 985.4	5	9		16.5		3	7					I 2 688.70	4	3	
15.3		7		I 3 075.32	2	5	5					88.2		3	
4 888.6	2	8		I 32.84	4	8	6					87.6		3	
11.8	1	6		03.8		2	6					I 75.95	10R	10	
02.1	1	6		I 2 990.99	2	4	5					I 41.50	4	4	
4 799.5	1	6		59.6		7	6					I 2 590.07	4	2	
87.1	1	6		26.2		1	6					I 44.2	4	2	
30.7		8		I 2 898.73	4R	6	6					I 10.51	4	2	
07.6		7		I 60.46	4R	8	7					03.3		5	
4 672.5		7		30.4		4	8					I 2 427.98	10R	10R	
29.9		7		I 2 780.23	8R	10	8					I 2 387.77	4	3	
19.4		7		I 45.00	6R	5	7					I 76.25	3	2	
07.3	2	5		2 602.9		2	6					I 64.58	4	2	
02.5		7		2 492.91	2	5	4					I 52.67	4	3	
4 590.8		7		56.52	4R	7	5					40.22		3	
52.2	2	7		37.22	1	5	3					14.67		3	
49.0	2	9		I 2 381.20	4R	5	5					04.80		4	
43.6		7		70.77	4R	5	4					2 291.51		3	
39.8	3	8		69.67	4R	5	4					83.3		3	
28.4		7		I 49.84	10R	6	4					42.7		3	
15.9		7		I 2 288.14	10R	3						29.0		3	
4 494.4	3	7		71.39	4	1						01.3		3	
74.4	4	8		28.7	2	1						2 110.7		2	
66.4	1	7		06.0	2							2 082.0		3	
61.1		8		05.2	2							00.6		3	
58.6	2	7		2 192.1		2						1 977.3		3	
31.6	4	8		83.0	1	1						I 51.2		3	
27.2		7		65.5	4	2						21.0		4	
20.9		7		44.2	4	1						I 18.9		4	
13.5		7		34	2	2						03.9		2	
12.0		7		13	2	3						1 889.8		2	
4 371	5	7		2 074		12						86.3		4	
52.9		8		31		10						I 79.1		3	
52.1	5	7		1 972		4R						71.1		3	
36.7	5	7		36		5						61.1		3	
24.0		7		1 890		4R						50.1		2	
15.7	1	7		1 742.9		20						45.7		3	
02.1		8		33.0		15						22.4		4	
4 299.4	3	6		00.2		10						02		5	
43.1		7		1 287		10						1 795		5	
28.2	2	7		67		40						84		5	
21.0		7		08		30						67		3	
07.8	2	7		1 171		15						40		4	
4 197.5	3	7		06		10						27		3	
90.2	2	7		1 093		20						26		4	
57.5		7		81		50						20		3	
4 082.4		7		09		10						1 699		3	



Au.—(Continued)			Ba.—(Continued)			Ba.—(Continued)			Ba.—(Continued)		
$\lambda$	A	S	$\lambda$	A	S	$\lambda$	A	S	$\lambda$	A	S
1 604		6	I 15 000	4		I 6 498.77	8R	4	I 3 377.4		
73		6	14 325	3		II 496.91	10R	10R	I 77.0	8	
59		3	211	3		482.93	7R	3	I 56.9	6r	
39		3	160	3		I 450.85	7	3	I 3 262.4	3R	
29		3	078	4		I 341.70	7R	3	I 3 071.60	8R	6R
22		4	13 957	2		II 141.74	10R	10R	I 2 785.26	6r	
00		3	811	4		I 110.80	8R	5	II 71.4	2	3r
1 590		3	I 207	4		I 063.16	8R	4	I 02.65	6r	2
62		3	057	1		I 019.49	7R	3	II 2 647.29	4	4
34		3	12 815	1		I 5 997.102	7R	3	II 34.80	5	8r
00		4d	554	3		I 71.714	10	3	I 2 596.68	6r	
1 488		4d	II 084	5		I 07.6	6	2	II 28.51		6r
35		4	11 978	2		II 5 853.7	8R	5	II 2 347.58	5	7
02		2	886	5		I 26.30	7R	4	II 35.25	6R	10R
975		20	608	2		05.71	5R	2	II 04.22	6R	8R
864		5	I 304	2		00.34	7	2	II 1 869		5
854		4	116	2		I 5 777.7	10R	5	II 1 694		6
832		5	016	4		5 680.17	5	1	74		4
458		1	10 692	2		I 5 535.53	10R	6	1 554		3
			II 651	8		I 19.11	8R	5	04		4
			474	6		I 5 424.63	7r	3	1 415		3
			I 326			II 4 934.10	10R	10R	1 331		2
			I 273	5		I 02.88	4r				
			234	6		II 4 899.96	8	10			
			I 189	1		I 4 726.46	8r	5			
			II 034	6		I 00.45	6r	1			
			002	3		4 691.63	7R	4			
			I 9 832	7		I 73.61	7v	2			
			713	2		I 28.83	5v	1			
			611	10		I 19.98	5r	1			
			527	10		4 599.75	6R	2			
			370.1	3		79.66	8R	8			
			219.7	2		73.88	6R	4			
			189.4	2		II 54.037	10R	10R			
			8 915.00	4		II 24.95	8	10r			
			860.96	4		23.25	8r	3			
			I 799.7	2u		05.94	8	5			
			654.03	4		I 4 493.64	5v	2			
			582.1	4		I 88.97	7v	2			
			567.6	3		31.91	7	6			
			559.91	10		02.55	8	6			
			210.32	10		4 350.38	8	5			
			147.8	2		I 32.91	4v	1			
			120.5	3		I 23.00	4v	1			
			I 7 911.35	6		I 4 283.12	8	8			
			I 905.772	7		II 4 166.04	5r	10r			
			839.577	5		32.44	5	3			
			780.500	8		II 30.68	8R	10R			
			672.099	7		I 3 993.40	8R	6			
			642.9	5		I 37.88	5	3			
			488.095	5		I 35.72	7r	6r			
			459.7	5		I 09.92	6r	6r			
			417.55	4		3 892.65	5				
			I 392.44	6		II 91.78	8r	8R			
			280.314	8R		89.32	5	2			
			228.815	5		3 630.65	8r	2			
			I 195.262	6		I 3 579.7	6r	2			
			II 120.30	6		I 47.7	4u				
			I 059.96	8R		I 44.7	6r				
			6 865.69	5		I 25.0	6r				
			I 693.86	6R	2	I 01.12	8R	2			
			I 675.29	6R	2	I 3 421.5					
			I 595.35	7R	3	I 21.0	10				
			I 527.323	8R	3	I 20.3					

B (28, 33, 36, 48, 80, 90, 91, 124, 191)			Be (35, 90, 91, 230, 273)		
$\lambda$	A	S	$\lambda$	A	S
II 3 451.2		10	23 110		
I 2 497.733	10R	10R	097	6	
I 96.778	9R	9R	22 239	2	
2 266.9		2	21 897	2d	
66.3		2	560	3	
I 2 089.6		2	17 571	2	
I 88.8		1	16 794	2	
III 67.9		2	15 951		
III 66.4			400	6	
I 1 826.41		1	393		
I 25.87			013	3	
II 1 624.4		8qn	006		
III 758.68		3	14 904	3	
III 758.47			13 227	6	
III 677.16		5	12 355	6	
III 677.01			329	4	
			141	7	
			10 674	4	
			283	5	
			II 5 274.28		4
			II 4 674.55		8
			4 572.69	8	1
			II 4 362.21		7
			I 3 322.303	8	2
			I 22.042	8	2
			I 21.969	8	2
			II 3 275.57		5
			II 3 198.01		4
			II 31.972	9	5
			II 31.324	9	10
			II 3 047.86		4
			I 2 651	10	10s
			I 2 494.720	7	3
			I 94.575	7	3
			I 94.532	7	3
			I 2 351.50	6	

Ba (59, 60, 62, 74, 75, 78, 90, 91, 135, 148, 163, 174, 224, 252, 258)		
$\lambda$	A	S
I 30 934	3	
I 687	2	
469	2	
29 791	4	
I 224	5	
27 751	3	
26 221	2	
I 25 516	5	
23 255	3	
22 313	2	
221	2	
I 21 477	2	
I 20 712	4	
19 988	3	
075	2	
18 204	2	
17 182	1	
065	1	



## INTERNATIONAL CRITICAL TABLES

## Be.—(Continued)

$\lambda$	A	S
2 348.62	8R	3
I 2 175.72	10	
I 2 056.71	4	
II 1 776.339		8
II 76.118		6
II 1 512.451		10
II 12.303		8
II 1 036.32		3

Bi (13, 59, 74, 75, 78, 90, 91,  
138, 154, 170, 200, 223, 276)

$\lambda$	A	S
25 554	1	
14 332	3	
12 691	3	
167	4	
11 995	1	
711	10	
556	1	
073	1	
10 540	1	
302	2	
106	2	
9 829	2	
9 657.2	10	
9 342.6	4	
9 058.6	2	
8 907.8	2	
8 761.5	3	
8 754.9	2	
8 627.9	1	
8 579.7	1	
44.5	2	
01.8	1	
8 210.8	10	
7 840.3	2	
38.7	3	
7 502.3	2	
7 441.3	1	
7 335.0	1	
7 036.2	2	
6 991.1	4	
6 809.1		7
6 600.1		7
6 497.5		4
76.2	3	
75.5	3	
6 134.85	5	1
28.1		4
5 861.14		4
5 742.55	6	
5 599.41	3	
52.24	8	3
5 209.28		10
5 144.50		6
24.4		4
4 797.5		3
33.8	2r	
29.9		3
22.7	8	8
22.5	10	8
22.2	10	5
4 561.15		8

## Bi.—(Continued)

$\lambda$	A	S
4 340.6		4
28.6		3
08.56	4	2
08.20	4	2
02.13		10
4 259.64		10
4 121.85	6	4
21.52	6	4
4 079.22		10
3 888.22	2	1
87.94	2	1
3 792.9		8
3 695.53		8
3 596.11	3R	4
10.85	6R	5
3 405.23	2R	1
3 397.21	5R	2
3 076.67	3	2
67.73	9R	6R
24.64	8R	4R
2 993.34	9R	4
89.04	9R	5R
38.31	10R	8R
2 897.98	10R	5R
09.63	8R	2
2 780.52	7R	4
30.50	5Rd	2R
2 696.76	6Rd	4R
27.93	8 R	4
2 524.52	7R	2
15.68	6R	1
2 489.4	5U	1
30.5	2u	
00.89	8R	7
2 328.2	2u	
09.3	4U	
2 276.57	5R	2
30.62	8R	4R
28.25	6R	2R
14.1	3	1
03.1	4u	1
2 189.59	6R	
77.3	6R	1
64.1	4R	
56.9	4R	
53.5	4R	
52.9	7R	
44.4		2
43.6		2
34.4	8R	1
33.6	7R	
13.8	3	
10.3	8R	2
2 061.7	8R	3
1 973.2		3
59.6		3
02.5		1
1 823.5	3	5
1 791.7	4	4
87.1	3	4
76.7	3	4
1 533.7	5	3
1 346		10
17		15

## Bi.—(Continued)

$\lambda$	A	S
1 306		10
1 051		10
45		10
967		3
791		2
670		1

Br (25, 86, 91, 104, 147, 195,  
268)

$\lambda$	S	G
6 682		2
31.8		5
6 560.0		4
6 350.8		10
6 149.7		10
23.3		3
18.7		4
5 940.6		4
5 852.2		5
30.8		7
5 719.0		4
11.0		4
5 657.6		4
00.7		4
5 589.9		8
36.3		4
5 490.4		7
88.8		6
66.2		5
35.1		5
25.0		5
22.8		7
5 396.5		5
32.0		10
04.1		7
5 272.7		4
38.3	2	8
5 183.9		4
82.4	3	7
64.4		5
5 054.7		4
4 979.77		4
30.6	1	5
28.7	1	5
4 848.80	1	6
16.72	8	8
4 785.48	10	10
80.33		6
76.43	2	7
67.1	2	8
66.07	2	5
42.70	3	8
35.47		5
19.76	3	8
04.83	10	10
4 693.30	5	3
78.70	8	8
72.58	1	6
52.00	1	6
22.7	3	8
14.6		6

## Br.—(Continued)

$\lambda$	S	G
4 601.4		5
4 575.77		6
42.93	2	8
38.75	1	5
29.80		5
25.6		8
13.47	1	5
4 490.48		5
77.78		10
72.64		8
41.74		8
25.13		5
4 365.58	4	8
4 291.38	2	6
36.85		6
23.85		6
4 193.45	1	6
79.62	1	8
75.76		5
40.22	1	6
35.64		5
4 024.04		5
08.78		6
07.30		5
3 986.53	1	8
80.43		10
80.01		5
68.65		5
55.35		8
50.60	1	7
39.70	2	5
35.16		6
29.57		6
24.09	2	8
23.36		6
20.68		6
19.6		6
14.26	1	10
3 891.64	1	8
71.23		6
57.21		6
34.71		6
3 794.00	3	4
3 693.5	3	
3 562.4	10	
40.1	8	
17.4	5	
06.5	5	
3 417	5	
3 396.9	4	
33.0	5	
3 282.1	3	
3 168	3	
3 074	4	
20.8	4	
2 968	4	
26	5	
2 892	3	
72	3	
2 660	3	
2 594	3	
57	4	
41	4	
22	4	



Br.—(Continued)		
λ	S	G
2 389.8	3	
86.8	3	
1 633.6		10
1 582.4		8
76.5		6
75.0		9
40.8		6
31.9		7
1 488.6		8
1 384.6		8
1 251.8		4

C (27, 32, 33, 60, 79, 90, 91,  
98.1, 154, 166, 167, 190,  
193, 262, 262.1, 287)

λ	A	S	G
II 7 236.19			8u
II 31.12			6u
II 6 582.85			8
II 78.03			10
III 4 652.68		7	
III 51.46		2	
III 48.70		3	
II 4 267.27			10u
II 67.02			8u
II 3 920.773			8
II 19.061			6
II 2 992.63			4
II 2 837.602			8
II 36.710			10
II 2 747.31			6u
II 46.50			4u
I 2 478.3	10	10	10
III 2 297.59	2	10	
III 1 930.98	5	7d	
1 657	6	6qr	
I 1 561.3	5	5	5
IV 50.9		3	
1 335.7	10	10	
34.5	10		
29.6	8		
29.1	8		
23.7	7	7	
1 176	10	15qn	
II 1 036.8		10	5
II 36.2			5
I 10.1	9	10	
III 977.02		12	
II? 904	4	10qr	
II 858.2	8	8	8
II 687.1	8	7	8
651	2	6d	
II 636.2		2	
II 594.9	4	5	
574.4		6	
II 560.5		2	
II 543.4		2	
III 538.4		7	
II 533.9		1	
III 459.7		6	
372		1	
313		1	

Ca (1, 61, 74, 78, 90, 91, 119,  
154, 158, 163, 170, 174,  
181, 192, 203, 250)

λ	A	S
I 22 656	4	
I 625	3	
I 610	1	
I 19 947	1	
I 936	3	
I 918	1	
I 865	4	
I 857	4	
817	1	
I 777	6	
I 507	3	
I 453	5	
I 311	4	
16 433	1	
I 200	3	
I 162	2	
I 145	2	
13 038	3	
I 12 822	5d	
I 10 345	10	
9 695	7	
9 547	7	
9 251	3	
II 8 662.1	9	
II 8 542.1	10	
II 8 498.0	8	
7 610	6r	
I 7 326.12	8	
7 202.18	8	
7 148.18	10	
I 6 717.7	8	2
I 6 572.75	2	1
I 6 499.64	5	4
I 93.762	8	5
I 71.68	5	5
I 62.57	6R	6
55.57	3	2
49.82	5	3
I 39.060	10R	8
I 6 169.60	7	3
I 69.08	4	3
I 66.49	4	2
I 63.80	4	2
I 62.20	10R	8R
I 61.32	5	2
I 22.24	10R	10R
I 02.73	8R	8R
5 867.62	4r	
57.49	10	10
5 602.84	8	5
I 01.26	8	4
5 598.46	10	8
I 94.47	8	6
90.10	10	6
88.74	10	10
81.96	8	4
I 12.93	8	2
5 349.46	10	5
I 5 270.27	10	10
65.55	8	8
I 64.23	6	5
62.23	6	5

Ca.—(Continued)

λ	A	S
5 261.70	6	5
I 60.39	4	3
I 5 188.84	6	5
41.65	8r	3
I 4 878.17	10r	8r
I 4 685.2	4v	1
I 4 585.91	2	8
I 85.84	6	
I 81.45	8	6
I 78.57	8	5
I 26.98	6	5
4 499.90		10
I 56.62	4	5
I 55.880	8R	8
I 54.780	10R	10R
I 35.682	8R	8
I 34.964	10R	10R
I 25.444	10R	10
I 4 355.2	6u	2
I 18.645	8R	8R
I 07.74	8R	8R
I 02.527	10R	10R
I 4 298.987	6	8R
I 89.362	8R	8R
I 83.003	8R	8R
I 40.44	4	2
I 26.728	10R	10R
I 4 098.6	4r	2r
I 3 973.7	6r	3r
II 68.473	10R	10R
I 57.07	6r	2
I 48.91	4r	1
II 33.673	10R	10R
I 3 875.7	3	
II 3 736.905	6	10R
II 06.03	6	8r
I 3 644.76	5	
I 44.39	10	4
I 30.96	5	1
I 30.73	6	1
I 24.10	6	1
I 3 487.61	6r	1
I 74.78	4r	
I 68.48	4r	
I 3 361.91	6v	1
I 50.19	6v	1
I 44.49	5v	
I 3 286.1	5	
I 25.8	4r	
I 15.1	3v	
II 3 181.3	4	10
II 79.34	6	10R
II 58.87	8	10R
19.66		8
I 3 009.21	2	2
I 06.85	4	4
I 00.87	4	2
I 2 997.31	3	2
I 94.95	3	2
24.33	8	
2 899.78	9	
2 493.00	7	
I 2 398.58	8R	1R
I 2 275.5	1	4R

Ca.—(Continued)

λ	A	S
II 2 208.7	3	3
II 2 197.8	3	3
II 12.7	2	3
II 03.2	2	3
2 040	4	
35	4	
II 1 851.3		7
II 43.7		6
II 40.2		10
II 38		9d
II 15.0		8
II 07.8		7
1 667		5
1 562		4
II 55		8d
II 53		7
II 1 434		6
902		10
840		6
832		10
718		6
688		5
669		6
655		6
537		5
410		6
404		6

Cb\* (78, 90, 91)

λ	A	S
6 828.14	4	
6 723.66	6	1
6 677.34	8	1
6 544.67	6	1
6 430.50	8	1
5 983.26	7	2
00.62	10d	2
5 866.5	6	3
38.66	8	5
19.47	6	3
5 787.53	6	2
29.2	6	2
5 671.1	7	1
65.57	6	3
64.72	6	2
5 551.38	6	2
5 437.29	7	2
5 350.72	7	3
44.15	10	5
5 276.20	10	3
71.53	9	3
5 180.30	6	2
64.36	7	2
60.33	6	3
34.73	5	2
5 095.29	10	3
78.95	8	3
39.04	6	2
4 989.0	5	2
24.84	3	8

\* Columbium = Niobium.



INTERNATIONAL CRITICAL TABLES

Cb.—(Continued)			Cb.—(Continued)			Cd.—(Continued)			Cd.—(Continued)		
λ	A	S	λ	A	S	λ	A	S	λ	A	S
4 816.33	7	1	I 3 554.62	10d	2	II 5 337.49	3	25	2 062.0		5
10.57	6	3	I 37.50	10	2	I 5 297.7	3		55.3		3
4 733.88	5	3	I 35.30	10	3	I 5 085.823	10R	10	04.2		5
13.48	5	3	I 10.30	3	8	II 4 881.73		10	1 995		3
08.26	7	4	3 498.62	10	2	I 4 799.912	10R	10	I 42		2
4 675.38	10	8	3 358.38	10		I 4 678.151	10	10	39		2
72.10	10	9	41.95	10	4	4 415.68	1	6	21.8		2
63.83	9	4	II 3 236.44	3	10	II 12.31		10	00.7		6
48.94	7	3	II 25.47	5	10	4 245.6		4	1 873.6		15
30.12	10	10	II 3 194.95	5	10	16.9		6	56.0		15
06.76	10	10	II 63.37	5	10	4 191.6		4	44.5		10
4 581.64	10	5	II 30.78	8	10	II 34.78		15	1 773.1		6
73.09	10	5	II 3 094.19	10	10	27.0		4	68.8		6
46.83	10	4	II 2 950.91	6	10	4 094.8		4	47.9		6
23.40	8	3	II 41.57	4	8	57.5		5	07.5		8
4 447.22	10	3	II 27.82	8	10	II 29.08		10	1 628.7		6
37.23	10	8	II 2 697.07	3	7	3 988.2		4	1 514		20
10.22	10	3	2 584.03	2	6	77.3		5	1 472		8
4 377.90	10	4	Cd (13, 16, 59, 74, 75, 81, 90,			76.6		5	66		8
51.60	10	3	91, 132, 154, 176, 204,			40.3		5	62		20
31.42	10	3	205, 206, 207, 247, 251,			3 852.1		3	1 397		20
26.37	10	3	273, 276, 284, 287)			I 3 729.06	4r		69		20
01.10	10	5	λ	A	S	I 3 614.4	7	7	847		10
4 299.63	8	4	I 39 086			I 12.875	8R	9	396		1
62.10	8	3	I 16 482	6		I 10.510	10R	10R	Ce (6, 61, 78, 90, 91, 145, 151,		
29.15	10	3	I 432	6		II 3 535.67		20	154, 155)		
17.95	10	3	I 402	2		II 3 495.36		15	λ	A	S
14.74	10	3	I 15 711	7		I 67.656	8R	10	8 772.08	3	
05.32	10	3	258	7		I 66.200	10R	8R	8 647.59	2	
4 192.07	10	3	I 154	10		II 17.40		10	12.62	2	
90.91	10	4	I 14 849	2		I 03.653	10R	10	8 560.60	2	
68.13	10	5	I 473	8		3 298.97	4	4R	8 495.64	3	
64.66	10	5	I 354	8		I 61.05	10R	7	8 396.20	2	
63.64	10	10	I 327	10		I 52.525	8r	6u	71.90	2	
52.63	10	5	I 13 979	10		II 50.29		25	63.82	2	
39.74	10	4	I 11 630	2		3 185.53		5	55.32	2	
37.13	10	4	I 268	4		I 33.167	2r	5r	10.22	2	
29.97	10	3	I 10 394.6	10		29.23		5u	00.58	2	
23.85	10	4	I 8 200.1	1u		3 095.5		5r	8 261.03	2	
00.97	10	6	I 7 399	5		I 80.828	8r	3r	45.10	2	
4 079.73	10	6	I 82.3	2u		I 2 980.622	8R	6	34.12	3u	
58.97	10	10	I 46.0	1u		I 2 881.24	4R	3U	8 171.32	2	
32.55	10	3	I 6 777.7	2u		I 80.78	8R	6	8 025.59	2	
3 966.23	10	3	II 25.83		15	I 68.3	6r	3r	02.66	2	
37.47	10	3	II 6 464.98		10	I 36.92	8R	6U	7 860.54	2	
14.71	10	3	I 38.4696	10	10R	I 2 763.9	6R	3U	59.05	2	
3 818.92	1	8	II 6 359.93		10	II 48.58		10	35.81	2	
10.48	10	3	I 29.94	5		I 12.6	6r	1u	7 797.73	2	
02.98	10	4	I 25.1	5	1	I 2 677.6	8d	3u	7 689.13	2	
3 798.11	10	4	I 6 116.12	3	1	I 39.50	6R	1u	7 397.78	2	
91.24	10	4	I 11.5	3		II 2 573.04	4	10	29.92	2	
90.14	10	3	I 6 099.1	5		I 53.6	4r		7 252.72	3	
87.08	10	3	I 31.4	3		2 469.76		4	38.38	2	
59.57	10	3	5 637.3	5		2 329.27	8R	6	7 150.21	2	
42.41	10	3	I 04.7	2		II 21.15	1	7	7 086.31	3	
40.80	10	5	I 5 598.8	3		II 12.88	4	10R	61.69	3	
39.82	10	3	5 497		10u	06.63	4R	3	30.98	2	
26.24	10	3	II 5 381.82		10	I 2 288.03	10R	10R	6 999.87	2	
13.05	10	3	II 78.12		10	67.47	4R	2	86.00	2	
3 697.84	10	3	78	3		II 65.03	4R	10R	24.80	3	
I 3 580.27	10	3	I 39	2		39.86	6R	3	6 899.07	2	
I 75.85	10	2	38.5		10	II 2 194.62	1	4R	98.49	2	
I 63.53	10	2				II 44.39	4R	6R			



Ce.—(Continued)			Ce.—(Continued)			Ce.—(Continued)			CL.—(Continued)		
λ	A	S	λ	A	S	λ	A	S	λ	S	G
6 774.27	2		5 117.14	4	1	3 709.29	8	3r	4 904.7	2	4
04.40	3		5 079.68	5	2	3 679.42	6	2	4 896.7	2	5
00.67	3		44.02	4	1	67.97	9	3	19.4	10	9
6 665.65	3		22.85	4	1	55.85	10	3	10.0	10	9
52.75	3		4 971.50	4	2	23.84	7	3	4 794.5	10	10
28.90	3		4 893.93	3	2	13.70	10R	2	81.3	3	5
06.87	3		82.44	4	3	3 577.45	8	4r	68.6	2	4
6 555.65	3		4 773.93	4	3	60.82	8	4r	4 601.0		4
13.63	3		37.24	4	3	39.08	7	2	4 572.6	1	5
6 473.69	3		25.09	4	2	17.38	7	2	26.3		5
67.40	3		14.01	4	3	3 488.55	7	1	4 490.0	1	3
66.89	3		4 684.61	4	3	85.06	8	2	75.3		4
58.06	3		54.28	4	2	76.84	6	2	69.4		5
6 393.06	3	1	28.15	10	10	42.38	7	1	38.6		4
71.13	4		06.41	4	5	26.20	8	1	03.4		5
43.98	4	1	4 593.93	10	10	3 377.13	7	2	4 389.8		8
10.03	3		72.28	10	10	66.56	7	1	87.6		5
00.22	3		62.35	10	10	44.76	7	2	79.9		8
6 295.58	3		39.74	10	5	04.84	7	1	73.0	2	6
72.05	4	2	28.47	10	5	3 285.23	6	1	71.6		5
32.47	3	1	27.35	10	5	72.25	7	2	69.5		6
28.98	4	1	09.18	4R	3	34.17	7	1	63.3		8
09.00	3		4 471.24	10	5	21.17	7	1	43.7	5	10
6 186.16	3		60.21	10	10	01.72	7	1	36.3	2	5
23.66	4		49.33	9	4	3 194.83	7	1	23.4		6
6 098.35	4	1	18.78	7	5	71.63	6R	1	07.6	3	6
69.48	3		4 396.58	3R	2	46.40	6	1	04.1	1	4
57.99	3		91.66	8	8	03.38	6	1	4 291.8	2	5
43.39	5	2	82.17	8	5	3 063.00	6	2	53.4	2	9
24.18	5		75.18	8	3	51.98	5	1	41.3		8
13.41	5		49.79	8	4	17.18	4	1	34.0		5
5 975.87	4		37.76	9	4	2 976.90	4	1	26.4		7
40.86	4	1	20.73	8	3	2 896.75	4		09.7		5
34.40	4		06.73	8	4	33.30	4		4 158.0	2	4
28.34	4		4 296.68	9	8	2 791.42	4		32.5	10	3
10.00	5R		89.94	9	6	2 696.06	4		04.8		4
5 871.58	3		55.79	8	3	51.02	4	1	4 032.2		5
62.49	4		48.67	8	6	1 373		20	3 914	2	5
38.12	4	1	22.62	10	5r	32		20	3 868.7	1	6
12.9	5		4 186.60	10	10	830		20	61	5	10
04.42	4		65.61	9	10	741		5	51.5	3	8
5 788.15	4		52.01	8	10	399		1	51.0		10
73.12	4		49.94	10R	10				45.7	2	8
68.94	4	1	37.64	9	10				45.4		8
43.54	5		33.82	10	10				43	2	5
25.84	4		06.89	5R	3				33.4	2	8
19.04	5		4 083.24	10	5				27.7	2	5
5 699.22	5	1	73.49	9	4				20.3	1	5
96.99	5	1	40.76	9	8				05.2	2	6
77.74	4	1	12.40	10	10				3 798.8	2	5
69.96	5	1	3 999.25	10	6				81.2		5
55.14	5	1	93.83	9	4				50.0		5
14.73	3		92.39	9	3				3 650.1	1	4
01.28	5	1	56.29	9	3				02.1	4	2
5 556.27	4	1	52.58	9R	8r				3 522.0		6
12.06	8	3	42.75	10	5				3 392.8		8
5 472.27	5	3	3 890.00	8	3r				53.3	3	7
09.23	6	3	78.37	9	2				40.3	3	8
5 393.39	7	3	75.04	6R	2				29.0		8
30.53	5	2	53.16	8	2				20.5	2	8
5 274.23	5	3	01.53	10	8				15.3	1	6
11.91	4		3 786.63	8	3				3 289.7	1	6
5 191.63	5	1	64.12	8	3r				59.2	2	4
87.44	6	2	16.36	9	3				3 191.4	3	7

Cl (2, 29, 31, 32, 85, 91, 125)

λ	S	G
5 634.9		1
5 457.1		3
44.2		3
43.4	1	5
23.2	2	6
5 392.1	2	4
21.3	1	4
17.8	1	3
5 078.2	2	4



INTERNATIONAL CRITICAL TABLES

Cl.—(Continued)			Co (12, 16, 24, 54, 75, 90, 91, 153, 154, 177, 216, 226, 267)			Co.—(Continued)			Co.—(Continued)		
λ	S	G	λ	A	S	λ	A	S	λ	A	S
3 139.2		6				7 908.8	10		5 647.22	8	1
3 076.6		7				7 871.4	6		I 5 590.73	8	1
71.3	1	6				69.9	6		I 30.77	8	1
63.0		6	19 779	3		55.9	7		I 5 483.35	10	2
2 996.5		5	18 274	2		40.1	7		54.55	9	1
2 782.4		6	176	3		38.2	8		44.56	8	1
10.37		6	17 080	3		7 734.3	6		I 5 369.59	7	1
2 691.49		6	005	5		12.7	9		62.76	8	1
88.03		6	16 574	3		7 610.3	6		53.48	7	2
85.40		5	447	2		7 590.6	6		I 52.05	8	2
84.75		5	388	3		54.0	8		43.38	7	2
65.5		6	257	5		7 457.4	8		42.68	8	2
61.5		4	133	5		I 17.4	8		I 5 280.63	5	1
58.7		4	15 210	2		7 388.7	7		66.49	6	1
24.72		6	14 958	3		I 54.6	6		I 30.21	5	1
20.07		6	681	2		7 285.3	7		I 12.70	5	1
16.99		8	611	4		7 193.60	8		5 176.07	6	
11.4		5	559	2		59.16	8		33.45	5	1
09.50		7	062	4		I 54.7	8		I 22.76	5	1
03.5		6	11 895	1		34.33	8		I 4 971.95	6	
01.2		5	634	2		I 7 084.97	10		I 4 867.88	8	8
2 580.7		8	453.4			54.04	8		I 40.28	8	8
77.1		6	340.8			I 52.85	10		I 13.49	8	10
32.5		7	293.5			27.82	8		I 4 792.87	7	7
19.5		6	275.5			I 16.6	10		I 49.69	8	3
2 471.1		4	10 366.6			6 937.8	7		I 4 682.36	7	3
48.6		4	284.6			6 872.38	7	2	I 63.41	8	4
34.5		5	272.9			I 14.96	10	1	I 29.38	8	4
03.2		5	236.4			I 6 771.05	10	2	4 596.90	6	3
2 370.4		4	213.3			I 6 678.81	6		94.62	6	3
59.6		4	210.8			32.44	6	2	I 81.62	8	8
2 283.9		4	206.1			17.30	10d	1	65.61	7	7
51.5		5	189.2			6 595.90	6	3	49.664	6	5
51.0		5	020.7			63.40	9	3	I 30.97	7	10
2 093.4		4	9 597.9	2		6 490.32	7	1	I 4 469.57	8	5
87.1		5	44.5	2		77.89	9		4 339.64	5	3
1 821.9		2	9 357.0	10		55.02	10	5	4 252.30	5	2
1 577.7		2	9 095.4	6		I 50.23	10	6	I 4 190.71	7	4
47.2		3	37.9	8		29.89	7		60.7	1	8
1 145.0		2	8 958.5	6		17.80	8	1	I 21.327	10R	10R
1 070.9		4	26.2	10		6 395.19	7	1	I 18.78	8R	10
14.9		4	04.7	8		47.79	10	1	I 10.54	9	10
08.6		4	8 870.8	4		20.35	10	2	I 4 092.40	8R	8
984.8		4	50.7	10		I 6 282.65	10	4	I 86.32	8	9
60.4		6	35.2	8		71.40	10		I 66.39	7R	5
888.0		4	19.2	10		57.61	10	3	I 45.40	8R	5
40.9		6	8 575.3	4		I 31.02	7	3	I 20.898	7R	5
VII 13.00		2	8 378.4	7		11.13	8	1	I 3 997.905	7R	10
VII 00.70		3	72.8	10		I 6 188.98	8	3	I 95.312	8R	10
787.8		4	8 299.0	5		22.68	10	2	I 74.731	5R	4
VI 30.31		4	69.4	8		07.93	7	1	I 57.935	6R	4
12.6		4	08.7	8		I 6 093.14	6	2	I 41.736	5R	4
663.2		4	8 193.1	8		86.66	7	2	I 35.974	6R	10
53.7		4	52.0	6		82.46	10	5	I 3 894.085	9R	10
V 39.24		5	16.4	7		49.06	10	2	I 76.84	8R	5
V 35.31		6	8 094.0	10		07.63	8	2	I 73.117	9R	10
V 33.18		6	66.5	7		06.30	8	2	I 61.168	7R	10
V 29.33		6	56.0	8		00.71	8	1	I 45.478	10R	10
586.9		4	43.3	8		5 991.88	10	5	I 42.06	6R	10
74.3		4	29.3	7		I 84.19	10	2	3 755.450	6R	4
61.5		4	22.2	7		46.51	8	1	I 45.50	6R	10
56.4		4	07.3	10		15.53	8	3	32.398	8	7
IV 38.08		3	7 987.4	7		5 890.48	7	2	I 04.06	8	7
			26.6	8		30.06	7		3 683.054	8	8



Co.—(Continued)			Co.—(Continued)			Cr.—(Continued)			Cr.—(Continued)		
	λ	A	S		λ	A	S		λ	A	S
3	676.555	8	6	2	886.45	5	2	25	816	1	
	39.44	10	2		15.55	4	1		785	1	
I	27.81	8R	4	2	766.22	4	2		709	1	
I	02.083	5R	4		45.10	4	3		665	1	
I 3	587.19	8R	10		31.11	4	2		584	2	
I	75.36	6R	5	2	675.99	4	4		560	1	
I	74.96	5R	4		63.53	4	10		490	1	
I	69.38	7R	10		48.65	4	10		460	2	
I	64.95	5R	4		32.4		10		18	717	
I	50.60	5R	3		574.36	3R			654	3	
I	33.361	6R	4		64.04	3	10		584	3	
I	29.814	8R	6		59.40	3	10		479	3	
I	29.037	4R	3		41.95	2	10		15	861	
I	26.853	9R	6	I	28.97	3R	2		680	3	
I	23.438	4R	5		19.8	1	10		13	462	
	21.57	5R	5		11.1	2R	4		11	611	
I	20.087	4R	3		06.4	3	10		483	4	
I	18.352	6R	7	2	464.2	2	8		392	5	
I	13.483	4R	4		47.7		10		337	4	
I	12.642	4R	6		32.3	3R	5		312	2	
I	10.419	4R	4		24.9	3R			158	9	
I	09.847	4R	5	I	15.3	3R	2		016	8	
I	06.316	6R	8	I	11.6	3R	3		10	906	
I	02.282	5R	6	I	07.3	3R	2		820	4	
I 3	495.683	6R	5	2	397.4	1	10		673	3	
I	89.404	5R	7		88.9	2	10R		486	4	
	85.345	7	3		78.6	2	10		082	2	
I	74.019	9R	8		63.8	2	10		9	948	
I	65.794	6R	5		07.9	2	6R		9	734.5	
I	62.808	6R	5	2	286.2	2	6R		9	670.5	
I	53.514	6R	10		76.6	3	1		9	574.2	
I	49.445	6R	5		13.9	3	1		9	447.0	
I	49.172	6R	5	2	196.6	5			9	294.1	
I	43.646	3R	6		65.6	3	2		90.4	10	
I	33.041	6R	6		05	4	1		9	142.6	
I	12.335	4R	4		2	011.5	7		41.1	1	
I	09.177	4R	6	1	974.1		4		40.4	1	
I	05.120	7R	10		69.4		5		9	035.9	
I 3	395.379	10R	5		56.6		5		I	21.8	
I	88.175	9R	5		55.2		4		I	17.08	
I	85.228	9R	4		50		4		I	09.97	
	77.06	8R	1		40.3		6		8	976.8	
I	54.383	6R	4		28		5			47.2	
	46.941	10	2	1	882.2		4		8	548.8	
I	34.151	5R	4		46		4		8	455.2	
	19.48	10	2	1	790.4		4			50.3	
3	283.45	10R	3		72.7		5		8	348.3	
	65.347	6R	1	1	631.6		3		8	235.9	
	60.814	7R	2		580		5		8	163.2	
	54.20	10R	2		74		5		7	942.0	
	47.17	7R	2		02		3			08.3	
	43.84	8R	2	1	128		3		7	722.9	
I 3	159.66	6R	1		937		5		I	7	462.4
I	58.76	6R	3		342		1		I	00.3	
I	49.30	6R	2	Cp, see Lu					I	7	355.97
I	47.06	7R	3	Cr (74, 75, 78, 90, 91, 108, 146,					I	6	979.81
I	39.94	7R	3	154, 181, 192, 212,							78.50
I	37.32	6R	3	213, 226)					I		25.23
I 3	086.77	6R	3		λ	A	S		I		24.15
I	82.61	5R	3		26	232	2		6	883.04	
I	72.34	5R	3		25	902	1		I	82.41	
I	44.00	8R	4			850	2		I	81.65	
I 2	989.59	6R	3						6	715.42	
I	87.17	5R	3								



Cr.—(Continued)			Cr.—(Continued)			Cr.—(Continued)			Cs.—(Continued)		
λ	A	S	λ	A	S	λ	A	S	λ	A	S
I 4 344.510	7R	8	3 014.92	6R	1	Cs (56, 61, 78, 90, 91, 174, 181, 182, 205, 223, 264)	202.6	1	4 870.0	10	6
I 39.72	5R	4	14.77	5R	1				II 30.2		6
I 39.45	6R	5	05.067	5R	1				4 763.6		5
I 37.57	6R	9	2 998.796	4R	1				II 4 646.5		5
I 4 289.725	10R	10	96.583	4R	1				23.1		4
I 74.802	10R	10	95.111	4R	1				16.1		4
I 54.340	10R	10	89.19	2	10				II 03.8		10
4 179.26	4	3	86.470	6R	2				I 4 593.18	10R	3
63.63	4	4	85.32	2	10				I 55.5	10R	4
09.58	4	1	79.74	2	10				II 38.9	2	6
4 058.79	4	3	71.90	2	10				II 26.7		7
26.17	4	2	67.64	4R	1				01.5		7
01.45	4	2	10.91	4R	1				II 4 435.7		4
3 991.13	6R	4	2 893.26	3R	1				05.3		7
83.92	7R	5	79.28	3R	1				II 4 384.4		5
76.68	7R	8	II 62.58	3	10				II 73.0		6
69.75	7R	8	II 55.68	4	10				00.6		6
63.70	7R	8	II 49.83	4	10				II 4 288.4		7
I 41.50	5R	3	II 43.25	5R	10R				II 77.1		9
I 28.65	6R	3	II 35.64	5R	10				64.68		10
I 21.03	5R	3	30.48	2	10				32.19		6
I 19.17	7R	5	22.38	2	10				13.3		6
I 08.76	6R	3	12.01	2	10				4 158.6		4
I 3 894.05	4R	3	00.77	1	10				II 4 068.8		6
I 85.22	5R	3	2 792.16	1	10				68.0		6
04.80	5	3	80.71	7R					39.8		9
3 749.00	4R	3	69.91	6R	1				06.5		6
43.88	4R	3	II 66.54	4R	10				3 974.2		6
43.56	4R	3	II 62.60	3	10				II 65.2		6
3 639.81	6R	5	57.11	4R	2				II 25.6		6
36.59	5R	3	52.87	3R	1				II 3 897.0		7
I 05.330	10R	10	II 51.87	3	10				88.4	1	2
I 3 593.484	10R	10R	II 50.73	3	10				76.2		
I 78.687	10R	10R	II 43.63	3	8				05.1		6
50.64	4	2	31.90	5R	1				II 3 785.4		5
3 433.60	5R	2	2 691.05	4	10				3 699.5		5
22.74	3	10	78.79	4	10				61.4		6
21.21	3	9	77.17	5R	10				08.3		5
08.76	3	10	2 591.86	4R	1				3 597.4		6
03.32	2	10	38.3		5				59.8		5
3 382.68	2	10	2 408.67	2	1				3 411.3		9
68.05	4	10	2 324.9		4				3 350		8
60.32	3	10	2 226.5	2	2				41		8
58.50	3	10	2 150.7	3	1				16		8
46.73	4R	1	33.5	3	1				00		8
II 42.58	3	10	2 039.3	3					3 268.3		10
II 39.80	3	10	34.4	2					11		6
07.05	1	8	1 816.4		10				3 152.7		8
3 217.40	3	8	1 018.7		3				49.6		8
09.18	2	10	04.4		3				3 067		10
3 197.08	3	10	925.5		2				2 977		6
80.73	3	10	885.2		10				63		8
II 32.053	4	10	840		3				38		8
II 24.974	4	10	681.3		5				31.1		10
II 20.37	4	10	67.1		5				2 894		8
II 18.65	3	10	48.7		5				87		10
3 053.883	6R	2	37.8		6				59		10
50.14	2	10	29.9		6				45		10
40.852	5R	10	19.9		6				38		8
37.049	5R	1	575.3		5				11		6
34.197	5R	1	469.8		4				2 776		10
21.57	6R	2	64.0		4				07		10
18.502	5R	1	56.8		4				00		8
17.58	6R	2	438.3		4						



Cs.—(Continued)			Cu.—(Continued)			Cu.—(Continued)			Dy.—(Continued)		
$\lambda$	A	S	$\lambda$	A	S	$\lambda$	A	S	$\lambda$	A	S
2 631		10	4 177.7	6	2	I 2 369.88	5	8	5 389.58	6	
00		8	I 4 063.4	6	1	56.63	2	4	80.68	6	
2 597		10	I 62.7	10	7	2 294.34	3	5	01.59	5	
73		8	I 22.70	10	8	93.85	6R	3	5 260.58	5	
44		10	I 3 861.75	3	1	76.24	1	4	5 197.66	8	
26		10	3 771.9	3	1	I 63.1	3R	2	69.64	6	
2 495		8	41.25	3	1	46.98	3	6R	39.58	8	1
2 274.5		10	00.54	3	1	42.60	2	6	20.01	5	
68.3		10	3 621.23	6	2	30.08	4R	2	5 032.98	6	
21.3		10	02.04	8	2	I 27.75	4R	2	03.86	5	
06.3		10	I 3 599.137	8	2	I 14.57	4R	2	4 957.41	10	2
2 180.2		9	33.74	7	1	2 199.62	4Rd	2	23.14	6	1
47.5		10	30.384	7	2	49	1	3	4 890.12	5	1
42.2		10	27.49	5	1	1 999.6	5	2	32.43	5	1
32.4		10	20.00	4	1	79.2	4	1	25.00	5	1
02.4		10	I 12.11	6	3	1 840		8	4 775.81	6	1
2 089.2		8	3 483.75	6	3	1 783		3	45.79	6	2
80.6		8	I 57.850	4	1	69		4	31.84	10	3
35.7		8	54.72	6	3	50		6	4 698.72	4	2
1 935.2		8	50.33	7	6	I 41		6	12.27	8	4
1 889.2		6	02.23	4	1	22		6	4 589.35	10	5
84.0		6	3 381.428	3	1	02		5	77.81	6	3
Ct, see Lu			65.36	6	2	1 687		6	03.25	5	2
Cu (3, 14, 59, 62, 74, 78, 90, 91, 111, 113, 170, 174, 181, 214, 223)			37.850	8	3	79		6	4 449.72	8	4
$\lambda$	A	S	17.20	5	2	72		6	09.40	8	3
I 18 229	5		07.950	9	7	70		6	4 375.33	5	2
I 194	7		3 293.92	4R	2R	52		6	58.50	5	2
I 16 653	4		90.546	10	6	42		8	08.66	5	4
I 008	5		79.80	5	3	1 594		5	4 295.02	6	5
I 8 092.77	10		I 73.965	10R	10R	788.3		6	56.33	8	3
I 7 933.23	10		I 47.549	10R	10R	77.3		5	25.14	6	3
7 570.1	5		43.15	6	4	452.8		7	21.12	8	3
6 905.9	6		31.17	4	2	358.0		5	15.13	6	3
6 741.4	6		08.20	6	2	29.2		5	11.74	10	5
6 672.23	5		I 3 194.10	8	3	24.5		6	4 194.85	8	4
6 485.16	5		46.82	6	2	155.7		0	86.80	8	4
74.20	5		42.43	7	2	Dy (70, 90, 91)			83.68	6	3
6 325.4	4		40.33	6	2	$\lambda$	A	S	67.99	10	4
6 268.3	6		28.67	6	2	6 899.40	4		46.06	6	2
I 5 782.15	6	6	26.10	7	3	35.51	6		11.35	8	4
I 00.24	5	4	16.33	7	2	6 747.96	3		03.34	8	8
5 554.94	2	1	08.60	8	5	6 667.93	6		4 077.98	10	10
35.8	1	1	3 099.92	6	3	6 579.42	6		46.00	10	4
5 292.54	4	4	94.00	6	2	6 486.62	5		00.50	8	10
I 20.06	6	5	I 73.82	5	2	21.95	6		3 996.72	5	4
I 18.203	10	10	63.42	7	3	6 386.89	5		78.57	6	10
I 5 153.26	8	8	36.10	8	2	43.32	5		68.42	10	10
I 05.545	7	6	10.843	7	1	6 259.12	10		44.69	10	10
5 016.63	2	2	2 997.37	6	4	6 168.47	6		3 898.54	6	10
4 704.60	4	2	61.183	9	6	6 088.27	6		36.49	6	4
4 674.78	5	3	2 882.95	6	3	10.85	5		06.25	6	10
51.17	8	7r	24.38	10	5	5 974.52	5		3 786.20	6	5
4 587.00	10	10	I 2 766.39	10	4	15.18	3		57.37	4	3
I 30.84	8r	2	13.6	1	5	5 868.18	3		24.42	5	5
09.39	6	3r	01.1	1	5	05.55	3		3 698.17	4	10
I 4 480.38	7	2	I 2 618.39	10R	3	5 740.23	3		94.75	6	10
4 378.2	8	8	2 529.43	1	5	02.91	4		76.56	3	10
4 275.13	8	8	06.4	1	6	5 685.57	4		45.40	8	10
48.97	6	4	I 2 492.15	5R	2	51.99	6		00.34	6	10
			73.46	1	4	00.68	5		3 576.89	6	3
			I 41.62	5	2	5 547.27	5		63.12	6	4
			00.10	2	5	15.40	5	1	50.21	8	10
			I 2 392.64	7	1	5 423.30	5		46.83	6	4



## INTERNATIONAL CRITICAL TABLES

## Dy.—(Continued)

$\lambda$	A	S
3 536.04	5	5
31.70	10	10
24.03	5	10
3 494.47	8	5
84.66	6	3
54.36	6	10
13.77	6	3
07.77	8	3
3 393.58	6	3
85.03	6	3
53.57	5	2
19.87	6	3
08.87	6	3
3 282.78	5	3
69.12	5	1
35.87	5	3
16.60	5	3
3 162.79	4	3
41.09	4	2
3 043.46	4	1
16.98	3	1
2 985.92	3	1
48.30	3	1
06.39	3	1
2 877.90	3	1
16.38	3	2
2 772.59	3	
2 634.80	3	1
00.17	3	
2 560.19	3	
2 422.75	3	

Em, see Rn

## Er (65, 66, 90, 91)

$\lambda$	A	S
7 680.00	3	
7 469.46	5	
7 316.29	3	
7 135.69	3	
7 001.44	3	
6 951.87	3	
6 897.53	3	
48.11	4	
6 759.88	4	
21.93	4	
6 616.75	4	
01.11	6	
6 583.47	5	
6 441.33	5	
6 388.19	6	
26.13	5	
08.79	8	
6 299.43	5	
21.01	6	1
6 076.46	5	
06.80	5	
5 902.10	5	
5 826.78	6	1
5 762.80	5	1
57.62	5	1
39.17	5	1
10.88	4	1

## Er.—(Continued)

$\lambda$	A	S
5 665.45	4	2
26.52	4	1
01.19	4	1
5 593.40	4	1
5 485.93	5	2
56.58	5	1
54.25	5	1
22.79	5	1
14.63	6	1
5 395.86	6	2
44.49	5	1
02.31	5	1
5 279.31	5	
55.93	6	2
18.22	5	2
5 188.91	5	2
33.83	5	2
27.41	5	2
5 042.06	5	2
28.90	5	1
07.24	5	1
4 951.73	8	3
00.09	5	4
4 872.09	5	3
61.60	5	1
48.83	6	2
31.14	8	3
20.33	6	4
4 795.50	8	3
62.65	6	3
51.55	6	2
31.61	6	3
24.54	6	3
4 679.07	6	5
75.61	5	10
30.91	6	4
06.62	5	3
4 563.28	6	3
52.12	6	4
22.67	6	
00.75	8	6
4 473.51	5	4
19.62	8	10
4 374.95	10	6
19.95	5	3
4 276.50	6	3
30.19	6	3
4 194.81	10R	2
51.11	6	4
23.10	6	
4 087.66	10	1
48.34	5	3
07.96	10	4
3 987.64	5	1
69.46	5	2
38.65	8	4
06.34	10	10
3 896.26	6	6
92.72	6	2
30.54	6	6
3 797.08	6	3
87.88	6	3
66.26	10	3
29.56	5	5

## Er.—(Continued)

$\lambda$	A	S
3 692.65		10
38.68	6	1
3 599.84	5	8
3 499.12	10	10
64.50	5	2
01.84	4	4
3 372.77	10	10
68.07	6	4
12.42	6	5
3 267.11	5	4
30.95	5	
3 154.28	4	3
3 070.77	4	2
25.91	4	2
2 964.52	4	3
10.36	5	4

## Eu (69, 90, 91)

$\lambda$	A	S
7 217.55	8	
7 194.80	8	
7 077.14	8	
6 864.57	10	
02.78	10	
6 645.20	10	10
6 501.57	7	
6 437.63	10	5
6 350.02	10	1
03.42	10	3
6 262.26	10	2
6 188.10	10	2
73.03	10	3
6 083.89	9	1
5 967.09	10	1
5 831.98	10	3
5 577.12	9	1
70.31	10	1
47.44	10	1
5 452.95	9	2
51.52	9	2
02.77	10	2
5 357.61	9	1
5 223.48	5	1
5 133.52	5	1
5 022.91	6	1
4 911.40	8	2
4 661.90	10	10
27.26	10	10
4 594.07	10	10
22.56	10	10
4 435.54	10	10
4 205.01	10	10
02.01	10	
4 129.72	10	10
3 971.95	10	10
30.51	10	10
07.10	10	10
3 819.64	10R	10
3 724.97	10	10
3 688.42	10	10
3 334.32	5	2
3 111.43	5	1
2 906.68	5	5
2 727.77	4	6

## F (26, 55.1, 103.1, 161, 217, 263)

$\lambda$	G	S
7 800.6	4	1
7 754.9	5	2
7 573.5	2	2
52.2	2	2
7 482.95	1	2
26	3	6
I 7 398.8	6	10
32.1	5	10
11.2	4	7
7 202.4	3	
I 7 037.56	9	
I 6 909.88	7	
I 02.49	9	
I 6 870.25	7	
I 56.05	10	
I 34.29	8	
I 6 774.00	6	
62.9	2	
6 569.72	2	
I 6 413.65	5	
I 6 348.50	6	
I 6 239.66	6	
4 446.8	10	
4 299.1	8	
46.3	10	
4 103.4	10	
4 025.1	10	
3 898.8	5	
51.7	5	
50.0	5	
47.1	5	
3 602.7	5	
01	5	
3 598.9	5	
05.8	10	
03.3	9	
01.9	8	
3 475.2	5	
73.5	5	
16.4	4	
3 262.7	3	
40.8	3	
01.1	3	
3 164.1	4	
51.7	3	
I 958.49	5	
I 55.53	6	
I 54.78	7	
I 51.81	5	
IV 679.19	5	
IV 77.17	5	
IV 76.06	4	
III 58.34	8	
III 56.86	6	
III 56.10	7	
II 08.06	8	
II 07.48	7	
II 06.95	4	
II 06.81	9	
II 06.27	7	
II 05.67	8	
IV 572.65	4	
II 46.84	4	



F.—(Continued)			Fe.—(Continued)			Fe.—(Continued)			Fe.—(Continued)		
$\lambda$	G	S	$\lambda$	A	S	$\lambda$	A	S	$\lambda$	A	S
III 467.70	7		7 748.285	4		5 930.17	5		I 5 107.646	4	1
III 30.15	4		7 664.304	4		14.16	6	1	I 5 098.706	7	1
20.1	1		7 586.07	7		5 883.842	4		I 83.344	4	1
378.6	1		I 68.931	4		62.35	4		I 79.743	3	1
Fe (40, 43, 109, 177, 178, 179, 193, 194, 197, 212, 215, 225, 245, 246, 260, 275)			31.18	4		5 763.01	4	1	I 79.228	3	1
$\lambda$	A	S	11.05	9		31.772	3		I 51.640	4	1
26 229	2		I 7 495.10	8		17.85	3		I 49.826	5	2
25 987	3		I 45.781	9		I 09.39	3	1	I 41.760	3	1
16 317	2		I 11.19	8		01.553	3		41.077	3	1
166	2		I 7 389.43	7		I 5 658.83	4	1	I 12.072	4	2
15 821	3		86.40	4		I 24.55	5	1	I 06.131	5	2
815	3		I 7 293.08	6		I 15.66	6	4	01.87	5	2
771	4		I 88.78	4		5 598.30	3	1	I 4 994.135	3	1
625	3		I 39.90	4		I 86.769	6	4	83.858	4	1
396	3		I 07.42	10		I 76.10	4	1	66.10	5	1
296	4		7 187.34	10		I 72.85	5	3	I 57.61	10	8
213	4		I 64.48	9		I 69.630	5	2	I 57.31	7	3
054	2		I 30.95	10		I 63.609	3	1	I 38.825	5	1
14 828	2		I 7 090.414	6		I 06.783	4	2	I 20.515	10	8
711	2		68.420	5		I 01.470	4	2	I 19.00	8	4
558	4		6 978.860	7		I 5 497.521	4	2	I 03.32	5	2
513	8		45.213	7		I 73.911	3	1	I 4 891.50	9	5
402	10		16.710	4		I 55.614	6	6	I 90.77	7	4
288	4		6 885.77	4		I 46.920	6	6	I 78.220	5	2
237	4		55.182	6		I 34.527	6	5	I 72.149	6	3
13 899	5		43.681	4		I 29.701	6	6	I 71.330	8	4
564	5		41.36	5		24.06	4	8	I 59.75	2	2
12 034	3		28.614	4		15.19	4	6	4 789.655	3	2
11 975	8		6 750.16	4		I 05.780	6	6	86.812	3	1
884	5		6 678.00	5		I 5 397.133	6	6	41.533	3	1
641	3		63.45	4		83.37	5	6	36.78	5	3
10 144	3		09.12	4		I 71.495	7	6	I 33.597	3	1
063	2		6 592.92	5	1	41.027	5	2	10.288	3	1
9 738.7	2		69.23	5		28.536	4	2	I 07.28	5	2
I 9 350.5	1		46.250	5	1	I 28.044	7	6	4 691.416	4	2
9 258.5	3		6 494.99	5	3	I 24.190	6	5	78.855	5	2
10.0	2		62.735	4		I 02.31	5	2	67.461	4	2
9 118.9	4		I 30.855	5	1	I 5 283.63	7	2	I 54.503	4	
00.5	2		21.36	4	1	I 81.80	5	2	47.438	4	2
9 089.4	4		11.67	5	1	70.360	8	4	38.019	4	1
88.2	4		08.04	4		I 69.540	10	8	I 32.918	3	1
79.6	4		00.02	5	3	I 66.566	8	3	30.128	3	4
8 999.5	4		6 393.61	5	2	42.496	3	1	19.297	4	1
8 866.9	3		36.84	4	1	I 32.95	8	5	11.290	4	2
38.4	2		I 35.34	4	1	27.191	8	4	I 07.662	4	1
I 24.254	6		18.026	4	1	I 16.28	5	1	I 02.946	3	2
I 8 688.640	7		I 01.52	5	1	I 02.340	5	1	I 4 592.656	4	2
I 61.92	6		I 6 297.802	3		I 5 198.715	4	1	47.853	3	2
I 8 468.42	7		I 65.142	4	1	I 94.948	5	1	I 31.154	5	2
I 8 387.786	8		52.565	4	2	I 92.35	8	2	I 28.621	7	6
I 31.95	6		46.34	4	1	I 91.46	7	2	I 4 494.570	4	5
I 27.06	8		30.732	5	3	I 71.601	7	2	89.745	3	1
8 220.42	7		I 13.439	3	1	II 69.03	2	5	I 82.262	4	4
8 085.21	5		6 191.566	5	3	67.492	8	4	76.024	7	4
I 46.086	5		I 73.344	3	1	66.288	3	1	69.387	4	3
I 7 998.98	6		57.733	2	1	I 51.916	3	1	66.556	5	3
45.887	7		37.700	4	3	I 50.844	4	1	61.657	4	2
I 37.18	9		36.623	4	3	I 39.48	8	3	I 59.125	5	3
7 832.24	6		6 065.491	4	2	I 39.27	6	2	I 47.724	5	2
7 780.595	5		27.058	3	1	33.68	5	2	I 42.346	5	2
			24.06	4	2	I 27.364	3	1	I 30.621	4	1
			5 952.745	4	1	I 23.725	4	1	27.313	5	2
			34.68	4	1	10.415	4	1	22.572	4	2



## INTERNATIONAL CRITICAL TABLES

Fe.—(Continued)			Fe.—(Continued)			Fe.—(Continued)			Fe.—(Continued)		
$\lambda$	A	S	$\lambda$	A	S	$\lambda$	A	S	$\lambda$	A	S
I 4 415.128	8	10	3 998.059	5	2	3 806.701	6	3	3 621.463	6	3
I 08.420	4	1	97.397	6	3	05.346	6	3	I 18.770	6R	6
I 04.754	8	10	83.963	5	2	I 3 799.550	6	5	17.789	6	3
I 4 383.549	10	10	77.745	5	2	I 98.513	6	4	12.079	4	1
75.933	5	2	71.327	4	1	I 97.518	5	3	08.861	6R	6
69.777	3	2	I 69.262	7	5	I 95.005	6	5	06.682	5	4
52.739	4	2	I 67.425	4	2	90.095	4	2	05.461	5	3
I 37.052	5	2	I 66.068	5	2	87.883	6R	4	03.206	5	3
I 25.767	9	10	56.682	6	3	85.950	5	2	3 589.454	3	1
I 15.089	5	3	56.461	4	2	I 67.195	6R	5	I 89.107	4	1
I 07.908	8	10	52.607	4	1	65.543	6	3	I 86.988	6	3
4 299.24	7	4	51.168	4	2	I 63.791	6R	6	86.115	5	3
I 94.130	6	4	49.957	4	2	I 60.053	5	2	I 85.709	5	3
82.408	6	3	48.780	4	2	I 58.236	7R	8	I 85.321	6	3
I 71.765	8	10	42.445	3	1	I 53.615	5	2	84.960	5	2
60.484	10	10	I 40.883	4	1	I 49.488	8R	10	84.664	5	2
I 50.792	8	6	35.817	4	1	I 48.265	6R	4	82.203	4	2
50.130	7	4	I 30.302	7R	4	I 45.902	6	4	81.197	8R	10
47.438	5	2	I 27.924	6	4	I 45.564	7R	5	76.761	4	1
38.82	4	2	I 22.916	6R	4	43.470	4	6	71.998	7	2
35.95	8	4	I 20.261	6	4	38.309	4	2	70.24	7	
33.611	6	3	18.646	4	1	I 37.135	7R	6	I 70.102	7R	10
27.439	7	4	I 17.186	5	2	I 34.868	9R	10	68.979	4	1
25.463	4	1	I 07.938	3	1	I 33.320	6R	3	I 65.382	6R	5
22.224	5	2	I 06.484	5	3	32.399	6	1	I 58.519	5	4
19.365	5	3	I 03.903	3	1	I 27.622	6R	5	56.881	6	2
16.188	4	1	I 02.949	7	5	24.380	6	2	54.928	8	4
I 10.357	6	3	I 3 899.711	6	4	I 22.565	6R	4	53.744	5	2
I 02.033	7	6	I 98.01	4	2	I 19.938	8R	10	45.642	5	1
4 199.099	6	5	I 97.895	4	2	16.449	6		42.080	6	3
98.313	6	3	I 95.660	5	3	I 09.250	6	4	41.089	6	3
91.44	6	3	93.396	4	2	07.922	5	4d	40.129	4	1
87.807	6	4	91.932	4	1	07.825	3		37.730	4	1
87.048	6	4	I 88.519	7	4	I 05.568	6R	4	36.558	6	3
84.895	4	2	I 87.053	6	3	04.464	5	2	33.196	5	2
81.760	6	4	I 86.286	7R	5	01.086	6	2	33.006	4	1
75.642	4	2	78.66	4		3 694.002	6	2	30.384	4	1
56.804	4	2	I 78.576	6R	5	89.459	6	2	27.796	4	1
54.816	4	2	I 78.022	6	4	I 87.459	6R	4	26.673	5	1
I 47.675	4	1	I 73.765	4	2	86.000	5	2	26.468	4	1
I 43.873	7	5	I 72.505	6	4	84.112	5	2	26.378	3	
43.420	5	3	I 67.221	3	2	I 83.058	4	2	I 26.167	5	2
34.683	5	2	I 65.527	6	4	82.24	6	3	I 26.02	4	2
I 32.062	7	4	I 59.913	7R	6	I 79.916	5	3	24.242	4	1
27.615	4	1	I 59.215	5	2	77.631	6	2	24.076	4	1
18.551	6	3	I 56.373	6R	5	76.314	4	1	I 21.265	5	3
14.453	4	1	I 50.821	5	2	69.524	6	2	I 13.821	5	3
09.810	4	2	I 49.970	6	4	59.520	5	1	06.500	5	1
07.494	5	2	43.261	5	2	55.467	4	1	I 3 497.844	5	3
4 076.638	5	2	I 41.052	6R	5	51.741	6	3	97.111	4	2
74.792	3	1	I 40.440	6R	4	49.509	6	3	I 90.576	6R	4
I 71.744	7	8	I 39.259	5	2	I 47.846	6R	6	89.673	4	1
67.986	5	1	I 34.226	7R	6	45.825	4	2	85.343	6	1
67.277	3	1	33.313	4	1	40.392	6	3	I 83.010	4	1
66.983	4	1	I 27.826	6R	8	38.299	6	2	I 76.707	5	3
I 63.600	8R	10	I 25.885	8R	8	37.862	4	1	75.653	4	
62.448	4	2	I 24.445	6R	5	34.336	5	1	I 75.456	6R	3
I 45.818	8R	10	21.182	6	3	32.041	6	2	68.849	4	1
21.871	5	2	I 20.430	8R	10	I 31.465	6R	6	I 65.865	6R	3
14.536	4	2	I 15.843	7R	10	31.098	5	1	59.917	4	1
09.717	5	2	I 12.967	6	4	25.149	4	1	I 52.280	4	1
I 05.248	7	6	I 07.541	4	2	23.188	5	2	51.919	6	1
						22.007	6	3	50.333	6	1



Fe.—(Continued)			Fe.—(Continued)			Fe.—(Continued)			Fe.—(Continued)		
$\lambda$	A	S	$\lambda$	A	S	$\lambda$	A	S	$\lambda$	A	S
3 447.282	6	1	II 3 227.757	4	5	I 3 031.643	5	2	2 838.120	6	1
45.153	4	2	25.791	8	3	31.219	4	2	32.435	6	1
I 43.881	6R	3	22.072	6	3	30.155	4	2	31.56	3	4
42.365	4	1	19.817	4		I 26.469	6	2	I 27.89	4	1
I 40.991	6R	4	19.58	5		I 25.848	5	2	I 25.69	4	1
I 40.612	7R	4	17.387	4	1	25.639	4	2	25.56	6	1
28.197	6	2	15.943	5	2	I 24.038	5	2	23.278	7	2
27.123	6	4	14.046	8	2	I 21.077	6R	3	I 13.289	9	2
26.640	6	1	II 13.32	4	2	I 20.645	6R	3	06.985	7	2
I 26.389	4d	1	12.000	4	2	I 20.498	5	2	04.524	7	1
24.289	6	2	11.696	4	1	I 18.989	5	2	2 797.777	4	1
22.663	4	2	10.836	5	1	I 17.633	5	2	91.79	3	1
18.511	5	2	10.245	4	1	11.486	4	1	89.81	3	1
17.845	6	2	05.400	7	1	I 09.576	5	2	88.107	6	2
13.136	7	3	00.479	6	1	08.145	5	2	87.94	4	
07.463	7d	4	I 3 199.527	6	1	I 07.287	4	1	83.69	3	5
04.354	6d	2	96.940	4	2	07.148	4	1	I 81.80	4	1
02.262	4	1	92.807	5	2	I 00.953	5	2	79.30	3	4
3 399.338	6	2	91.664	5	1	00.454	4	1	78.85	4	1
94.591	4	1	88.838	5	1	2 999.517	5	2	I 78.228	6	1
92.658	5	2	I 84.901	4	1	I 94.436	6R	3	I 74.73	4	2
92.309	4	2	81.53	4	1	90.396	4	1	73.23	4	1
83.985	5	1	I 80.765	4		I 87.296	5	1	I 72.112	6	1
83.698	4	1	80.227	8	2	II 84.834	4	6	72.08	4	
80.115	5	1	78.014	6	1	I 81.448	4	2	I 67.518	7	5
79.024	4	1	75.449	6	1	I 73.237	4	2	I 66.91	4	1
78.683	4	1	71.35	4	1	I 73.137	4	2	64.33	4	1
70.787	6	2	66.442	4	1	I 70.108	4	2	63.11	4	1
55.234	4	1	61.947	5	1	I 69.483	4	2	I 62.029	5	1
47.932	4	1	60.660	6	1	I 66.901	6R	3	61.81	4	
41.912	4	1	57.878	4	1	I 65.258	5	2	I 61.785	5	2
37.670	4	1	57.042	4	1	59.997	4	2	59.816	4	1
28.870	4	1	51.347	6	1	I 57.370	5	2	57.32	4	1
23.741	4	1	43.985	6	1	I 53.943	4	2	I 56.332	5d	1
14.746	6	1	42.891	4	1	50.25	6	1	II 55.74	8	10
06.358	8	3	42.447	4	1	48.44	4	1	I 54.03	4	1
05.978	8	3	I 34.114	5	1	I 47.878	5	3	53.69	4	1
3 298.137	5	1	29.337	4		47.66	4	4	53.29	4	5
92.60	5	1	I 25.664	6	2	44.40	4	4	50.87	4	
92.03	5	1	20.436	4	1	I 41.345	8	3	I 50.15	6	2
90.993	4	1	19.496	4	1	37.81	6		II 49.324	7	10
86.761	8	3	I 16.636	5	1	I 36.904	7R	2	49.183	4	
84.593	4	1	I 00.671	4	3	I 29.006	7	1	II 46.987	7	8
82.90	4	1	I 00.309	4	2	II 26.58	7	3	II 46.486	7	10
80.265	5	1	I 3 099.97	4	4	18.029	5	2	44.53	5	1
71.008	6	2	I 99.901	4		I 12.160	8	2	I 44.07	8	1
68.25	4		I 91.582	4	2	2 899.420	4	1	II 43.199	6	8
65.623	6	2	I 83.747	4	3	95.04	4	1	I 42.41	6	1
65.053	3	1	I 75.725	5	3	94.51	4	1	I 42.258	4	1
64.521	4	1	68.180	4	1	87.81	4	1	II 39.551	9	10
57.599	4	1	I 67.253	5	3	77.303	5	1	I 37.31	6	1
54.368	4	2	67.123	4		I 74.177	7	1	II 36.971	4	4
51.24	5	1	I 59.092	5R	3	72.34	4	3	I 35.479	8	2
48.211	6	1	I 57.453	5	3	I 69.310	6	1	34.27	4	1
46.973	4	1	55.268	4		66.63	4	1	34.01	4	1
44.189	8	2	53.071	4	1	I 63.867	5	1	I 33.580	9	2
39.441	8	2	I 47.611	6	3	63.434	4	1	30.74	4	3
I 36.227	5	1	45.086	4		I 58.898	4		28.03	4	1
34.621	5	1	I 42.673	5	2	51.800	8	2	27.541	5	6
33.975	6		I 42.028	4	1	48.718	4	1	27.39	3	2
33.056	5	2	I 41.748	4	2	45.595	4d	2	26.24	3	1
28.262	4	1	40.434	4	2	43.97	7	2	26.06	4	1
27.816	4	5	I 37.393	5	3	43.63	5	1	24.96	4	



INTERNATIONAL CRITICAL TABLES

Fe.—(Continued)			Fe.—(Continued)			Fe.—(Continued)			Fe.—(Continued)		
λ	A	S	λ	A	S	λ	A	S	λ	A	S
2 724.89	3	3	2 575.76	4	1	2 404.43	4	2	2 199.5	5	
I 23.581	6	2	74.37	3	4	2 399.24	6	5	96.0	5	
I 20.909	7	2	70.86	3	3	II 95.63	8	4	91.8	5	
19.43	4	2	70.54	3	1	95.42	4	3	78.1	5	
19.036	7	2	66.921	4	3	89.98	4		71.3	5	
18.45	4	1	63.482	5	4	88.63	6	3	66.8	6	
14.88	4		II 62.541	5	5	83.25	4	2	65.8	5	
II 14.417	6	5	I 49.62	6		II 82.04	8	10	59.9	5	
11.66	5		44.72	4		80.76	4	3	51.7	5	
10.55	4	1	43.926	5	1	79.28	4	3	44.4	5	
08.58	4	1	42.11	5	1	II 75.19	4		39.7	5	
06.59	5	2	I 40.977	6		II 73.73	6	4	06.4	4	
04.00	3	4	37.18	6		73.62	4		2 093.7	4	
2 699.11	4	1	I 35.612	6		70.5	6		84.2	4	
96.29	5		33.7		5	II 68.59	7		63.7	3	
96.00	4		I 29.84	6		66.59	5		40.6	3	
94.54	4		I 29.139	6	1	64.83	8		20.6	3	
92.61	3	4	I 27.44	4	2	62.1	8		00.3	3	
89.84	4	1	25.4		4	II 60.3	5		1 953.6		2
89.22	5	2	I 24.29	6	1	59.11	6		14.2		3
84.76	3	4	23.66	4	1	54.9	6		13.3		4
81.59	4		I 22.86	4	3	51.2	4		1 895.6		4
79.064	6	2	I 18.11	6	1	48.3	5		69.7		4
66.82	4		17.66	4	1	48.12	5		43.9		2
66.64	3	4	12.37	4		44.3	4		1 788.3		5
64.67	3	4	11.8		5	43.50	7		87.0		5
56.15	3	1	I 10.839	6	1	38.01	6		24.0		2
51.72	3	1	07.90	4	1	32.80	6		18.3		2
41.65	3	1	2 496.54	5	1	27.39	6		02.0		3
35.82	4	1	93.3		8	13.1	5		1 630.9		2
32.25	4	1	I 91.16	4		10.01	5		1 597.7		2
31.33	6	3	I 90.66	4		00.1	5		38.3		2
31.05	6	4	I 89.76	6		I 2 299.2	5		32.3		2
30.08	3	2	I 88.15	4	2	I 98.2	7		25.5		2
I 29.60	5	3	87.37	4	1	I 97.8	6		1 430.6		2
28.300	6	8	86.07	4	1	92.5	5		09.4		2
II 25.68	8	4	86.69	4	1	91.1	6		1 387.8		2
25.50	4	3	86.38	4	3	90.6	5		73.9		2
23.54	4	1	I 84.19	6		89.0	6		1 272.2		2
21.674	6	4	83.54	4		87.6	5		60.8		2
20.70	3	2	83.28	5R	1	87.3	5		54.1		2
20.42	3	2	I 79.78	4	1	80.2	6		28.9		2
19.08	3	2	74.82	5	2	79.9	6		1 186.4		2
18.03	4	1	73.16	4		I 76.0	5		43.4		2
17.624	6	6	I 72.91	4	1	74.1	5		1 062.1		2
13.84	8	8	I 72.87	5		72.8	5		31.8		4
II 11.88	8	10	72.35	5		67.6	5		17.6		6
07.098	7	10	68.88	5	1	67.1	5		06.0		2
06.83	5		65.16	5		66.9	5		983.8		3
2 599.57	3		I 62.65	6	1	65.2	5		29.2		3
II 99.40	6	10	I 62.19	6	1	60.8	6		863.2		3
98.377	7	8	57.60	6	1	55.8	7		59.9		4
92.80	4	4	53.48	4	1	53.2	6		669.9		4
II 91.55	4	4	I 47.72	4	2	51.9	6		66.9		4
88.006	5	3	44.5		4	49.2	7		09.1?		9
87.96	3		43.87	4	1	48.9	6		02.4		4
II 85.884	7	10	42.57	4	1	45.6	6		552.1		7
84.542	4	1	39.75	4	1	40.6	5		417.5		4
II 82.591	4	4	13.31	6	3	31.2	7		392.9		7
82.31	4		11.07	6	3	29.1	6		81.1		4
77.94	4	3	II 10.53	6	5	21.3	4		65.8		5
76.87	4	3	06.66	6	4	13.6	4		294.3		2
76.70	4		II 04.89	6	6	00.7	5				



Ga (46, 78, 90, 91, 149, 269,  
271, 282)

$\lambda$	A	S
I 6 413.74	8R	
I 6 396.8	10	5
4 864.9		5
4 172.05	10R	10R
4 033.01	10R	10R
3 806.8		5
3 575.3		7u
3 004.1		6
I 2 944.20	5R	1
I 43.65	10R	2
I 2 874.24	10R	2
2 780.2		9
I 19.66	3	8
I 2 659.87	2	7
I 2 500.18	2	7
I 2 450.07	1	4
18.70	1	4
2 371.30	1	3
38	1R	
2 294	1R	2
1 845.0		8
13.9		9
02.3		7
1 799.2		7
1 625.3		7
1 586.3		8
34.5		10
1 495.4		10
83.9		6
14.4		10
1 338.1		7
03.5		10
1 299.5		9
95.9		10
93.5		6
85.3		7
79.2		7
67.1		7
64.6		6
58.8		9
28.0		7
1 195.0		6
92.9		6
70.4		9
63.5		6
56.1		7
36.9		5
35.9		5
33.6		6
26.1		5
20.6		5
02.7		7
1 050.2		6
989.5		6
938.5		6
909.3		5
874.4		6
860.4		5
839.9		5
828.8		5
800.4		5
645		2

Ga.—(Continued)

$\lambda$	A	S
511		3
509		3
425		4
124		0
Gd (68, 90, 91, 144)		
$\lambda$	A	S
7 846.36	3	
7 733.50	4	
7 563.02	6	
7 464.37	4	
7 394.91	4	
24.91	5	
13.28	4	
01.24	4	
7 262.7	5	
52.72	5	
01.43	4	
7 189.64	5	
72.30	6	
68.3	10	
47.37	5	
22.58	5	
18.90	4	
7 068.07	4	
54.61	4	
50.97	4	
37.24	5	
06.13	5	
6 996.77	10	
91.89	6	
85.86	7	
57.71	4	
16.58	7	
6 887.65	5	
57.14	5	
46.61	8	
28.30	6	
6 752.67	5	
6 634.4	5	
6 305.16	5	1
6 114.07	6	1
5 913.56	4	I
5 754.20	5	
51.85	5	
33.86	6	1
01.35	5	
5 696.20	8	
43.24	5	
17.91	5	
5 535.16	7	
5 393.64	8	
70.69	5	
53.21	5	1
50.36	5	1
42.98	5	1
5 155.84	6	1
03.46	5	1
5 092.24	5	2
15.03	6	2
4 821.69	6	2
01.03	5	3
4 786.80	5	1

Gd.—(Continued)

$\lambda$	A	S
4 767.23	6	2
58.67	6	2
43.64	6	3
32.58	5	4
28.46	6	4
4 683.34	5	2
01.03	5	5
4 597.90	4	5
96.97	4	4
82.50	5	3
40.01	4	10
19.62	5	3
06.24	6	2
4 476.13	5	3
38.23	5	8
36.18	6	10
22.44	6	3
21.27	3	8
19.04	5	8
06.67	4	10
01.86	5	3
4 387.63	5	3
47.25	5	3
46.45	8	2
42.18	10	10
41.25	7	5
27.11	8	4
25.66	9	5
16.05	5	3
4 280.54	7	5
62.09	9	10
51.75	8	10
38.77	5	4
25.87	7	3
25.10	5	3
17.15	5	5
14.97	6	5
12.00	7	5
4 197.68	5	5
84.28	9	10
37.10	6	8
32.29	5	5
30.39	10	10
4 098.91	5	4
98.64	8	6
85.59	8	8
78.73	5	3
78.46	5	4
73.80	8	8
70.36	9	5
63.46	10	5
49.90	8	6
49.44	6	4
37.89	7	5
37.34	9	6
3 994.20	5	3
59.51	7	6
57.69	5	5
34.81	6	3
16.57	9	8
3 894.72	6	4
52.50	10	8
51.00	7	5

Gd.—(Continued)

$\lambda$	A	S	
3 850.69	7	4	
13.99	9	6	
3 796.43	9	10	
70.70	4	6	
68.40	10	10	
58.29	5	4	
43.41	7	10	
30.87	5	5	
19.48	9	10	
16.38	5	4	
12.71	6	10	
3 697.74	5	5	
87.76	5	5	
71.24	10	8	
64.64	7	10	
56.15	7	8	
54.64	7	8	
46.19	10	10	
13.42	5	4	
3 592.69	5	8	
84.96	8	10	
49.37	7	10	
45.78	9	10	
3 494.41	5	5	
81.83	5	5	
81.33	6	8	
50.38	5	6	
40.06	7	6	
39.21	6	5	
22.46	8	10	
18.72	7	4	
16.93	5	4	
3 362.25	6	10	
58.60	7	8	
50.48	7	10	
3 145.00	5	4	
00.51	8	8	
3 082.00	10	6	
34.06	7	6	
32.85	7	8	
27.60	6	6	
10.15	5	6	
2 999.06	5	4	
55.50		10	
04.73		10	
2 717.30		8	
2 679.41		8	
55.59		6	
28.12		10	
2 564.51		6	
Ge (46, 90, 91, 123.1, 161.1, 228, 231)			
$\lambda$	A	S	G
6 484.2			5
6 021.04			10
5 893.42			10
5 701.88			4
5 691.94			6
21.41			6
06.98			1
5 564.72			5
5 229.37		6	
5 178.57			7



Ge.—(Continued)				Ge.—(Continued)				H.—Second spectrum.— (Continued)		H.—Second spectrum.— (Continued)	
$\lambda$	A	S	G	$\lambda$	A	S	G	$\lambda$	G	$\lambda$	G
5 134.71			10	847.9		5		6 299.40	6	4 447.56	5
31.69		7		760.3		3		38.37	7	12.25	5
4 854.74	6			547.0		1		24.81	9	4 212.51	6
14.70		9	8	Gl, see Be				6 199.38	6	05.10	7
4 743.8		2		H (51, 89, 120, 165, 187.1, 202, 208, 218, 236, 278)				82.98	6	4 177.07	6
I 4 685.84	5	10		First spectrum (G)				35.35	8	71.29	5
4 291.56		3u		74 000				27.3	6	4 087.75	4
60.81		10		40 500				21.78	10	69.65	6
I 26.73	7	10		26 300				6 095.98	6	62.49	6
4 179.0		10		18 751				90.93	6	3 991.9	4
I 3 269.50	10	10		12 817				79.80	9	90.03	4
I 3 124.83	10	5		10 900				70.00	7	He (93, 185, 202, 203, 241)	
3 067.04	7	1		9 500				31.9	10	$\lambda$	G
I 39.09	10R	10R		6 562.85				27.98	6	I 40 540	
2 845.4		4		62.73				18.30	9	I 20 581	20
29.01	3	2		4 861.327				5 982.55	7	I 10 830	5
2 793.94	3	2		4 340.465				75.44	9	I 829	1
I 54.59	10	10R		4 101.735				49.91	7	I 7 281.35	3
40.44	8	7		3 970.074				38.62	7	I 7 065.19	5
09.68	10	10R		3 889.06				31.4	7	I 6 678.149	6
I 2 691.35	10	10		35.40				5 888.16	6	I 5 875.620	10
I 51.58	10	10R		3 797.91				36.0	7	I 4 921.928	4
I 51.18	10	10R		70.06				12.58	9	I 4 713.143	3
44.18	2	2		50.15				5 775.0	6	I 4 471.479	6
I 2 592.55	10	10R		34.37				36.86	7	I 4 387.93	3
I 89.20	3	5		21.95				31.90	6	I 4 143.76	2
56.29	1			11.98				5 688.20	6	I 20.81	3
I 33.24	3	6		03.86				5 537.45	6	I 4 026.19	5
I 2 497.97	3	7		3 697.15				05.5	5	I 3 964.73	4
17.28	3	10		91.55				5 481.09	5	I 3 888.65	10
2 379.15	1	3		86.83				34.84	5	I 19.60	4
27.93	1	3		82.82				19.90	6	I 3 613.64	3
14.22	1	3		79.35				5 388.2	7	I 3 447.59	2
2 198.71		2R		76.34				66.0	5	I 3 203.17	8
1 733		6		73.7				36.51	5	I 3 187.74	8
1 500.6		6		71.34				03.16	7	I 2 945.10	6
1 402.8		6		69.42				5 266.04	5	I 2 829.06	4
1 393.8		8		67.7				5 196.38	5	I 2 763.80	2
1 237.0		6		66.1				13.18	5	I 33.24	7
29.8		10		64.6				5 084.84	5	I 2 511.22	5



Hf.—(Continued)			Hf.—(Continued)			Hg.—(Continued)			Ho.—(Continued)		
$\lambda$	A	S	$\lambda$	A	S	$\lambda$	A	S	$\lambda$	A	S
5 040.8	6	6	2 647.3	6	6	I 2 967.28	5	8R	3 796.73	10	10
37.3	6	1	41.4	6	6	I 2 893.6	5	5	57.26	10	10
18.1	6	4	38.7	6	6	II 47.7		8	48.19	10	10
4 975.2	6	5	22.8	6	6	I 03.5	4		3 685.16	3	8
4 800.5	6	6	2 571.7	5	6	I 2 752.8	4	4	62.28	10	5
4 620.8	6	5	51.4	5	6	2 698.9	3		27.18	8	8
4 598.9	6	6	16.9	6	6	I 52.0	5	2	26.68	10	8
4 417.9	4	6	13.0	6	5	I 2 536	10R	10R	3 598.77	10	10
4 356.3	5	6	12.7	6	5	I 34.8	4	2	74.80	5	10
50.5	4	6	2 469.2	4	6	I 2 482.7	3		56.77	8	10
36.7	5	6	60.5	6	6	I 2 399.4	3		46.00	10	10
4 232.4	4	6	47.2	5	6	I 78.3	3		15.58	10	10
4 093.2	6	6	17.7	5	6	II 2 224.7	4	4	3 494.8	10	10
44.4	8	3	10.1	5	6	II 1 942	10	5	84.8	10	10
3 918.1	6	6	2 351.2	5	6	I 1 849	10	10	74.26	10	10
3 719.3	6	6	Hg (14, 45, 82, 90, 91, 135, 164, 203, 204, 205, 206, 265, 273, 276, 283, 287)			1 798.7		9	61.96	10	10
01.1	5	6				38.3		8	56.00	10	10
3 682.2	6	6				1 677.9		10	53.13	10	10
44.3	6	6				II 50		10	28.10	10	10
16.9	5	6				1 599		7	25.35	10	10
3 569.0	5	6				92		8	21.62	10	10
61.6	6	6				27		5	16.46	10	10
52.7	5	6				I 1 269.7		5	14.90	10	10
05.2	6	6				Ho (77, 90, 91)			10.25	10	8
3 479.2	6	6				$\lambda$	A	S	3 398.97	10	10
10.2	5	6				6 694.3	7		43.56	10	10
3 399.8	6	6				29.0	10		3 289.37	5	10
52.0	6	6				04.9	10		3 181.50	4	10
32.7	6	6				6 550.9	10		71.71	5	8
18.0	5	6				6 372.6	10		66.61	5	8
12.9	6	6				05.4	10		2 936.77		10R
3 255.3	5	6				6 255.7	10		2 774.70		10
53.7	6	6				34.2	10		2 433.0		10
3 194.2	6	6				6 133.6	10		I (91, 152, 268, 289)		
76.9	6	6				6 081.8	8		$\lambda$	S	G
72.9	5	6				5 982.9	10		6 585.0		4
62.6	5	6				48.0	10		60.3		4
45.3	5	6				33.7	10		6 488.1		4
34.8	6	6				21.8	10		6 359.1		4
09.1	6	6				5 883.0	10		39.5		6
01.4	6	6				60.3	10		37.9		4
3 080.8	6	6				5 691.5	10		6 293.9		6
72.9	6	5				74.7	10		57.4		4
67.4	6	5				5 566.5	8		04.7		6
31.2	5	6				4 742.0	10	3	6 127.4		8
16.8	6	5				4 649.8	8	1	6 082.3		10
12.9	6	6				29.1	8	5	74.9		6
2 975.9	5	6				4 356.72	8	8	23.9		6
68.9	6	5				50.73	10	5	5 950.1	1	10
29.6	6	5				4 254.42	10	8	5 893.8		8
19.6	6	6				4 173.22	10		30.0		6
16.5	6	5				27.15	10	5	5 787.1		6
2 898.3	6	5				08.5	10	5	74.8	1	10
66.4	6	6				03.84	10	10	39.5		10
61.7	6	6				4 065.08	10	5	38.5		10
61.0	5	6				53.92	10	8	10.4	1	10
22.7	6	6				45.44	10	10	5 690.8	1	10d
20.2	6	6				40.81	8	3	78.1	1	10d
2 773.4	6	6				3 891.01	10	10	25.7	1	10
38.7	5	6				88.96	10	10	12.9		6
06.7	6	5				61.68		10	5 598.7		6d
05.6	6	6				54.07	4	10	5 496.9	2	10qn
2 683.4	5	6				10.73	10	10	93.3		8d



## INTERNATIONAL CRITICAL TABLES

I.—(Continued)			I.—(Continued)			In.—(Continued)			Ir.—(Continued)		
$\lambda$	S	G	$\lambda$	S	G	$\lambda$	A	S	$\lambda$	A	S
5 491.5		8d	3 055.2	10	3	1 533.5		9	4 938.07	10	
64.7	5	10	38.4	4	5	21.6		9	4 778.15	4	2
37.9		8	2 062.1		10	III 1 488		8	4 616.37	6	2
35.7	1	10	1 876.4		7	35		5	4 426.29	6	4
07.3	1	10	44.5		9	06		8	4 399.48	6	8
05.3	1	10qr	30.4		10	1 381		9	11.50	5	4
5 369.7	1	10	1 782.9		9	20		7	4 268.09	4	5
45.1	3	10	1 642.5		7	1 233		6	59.12	4	2
38.2	3	10	41.1		7	22.5		6	4 115.80	4	5
09.0		8	1 518.3		7	1 082		6	4 069.93	4	8
5 269.4	1	10	14.8		9	54		6	33.77	4	4
65.2	1	10d	1 459.2		6	31.5		5	20.05	5	8
45.6	4	10	58.2		6	973		3	3 992.14	6	6
34.6		10	25.7		8	54.7		4	76.33	5	10
16.2	1	10	1 390.9		5	882		4	15.38	4	6
04.1		10	55.5		6	752		1	3 895.6		8
5 161.2	10	10	36.7		6	684		2	00.10	6	6
19.3		10	1 234.2		3	583		1	3 747.21	5	6
5 065.5		6	In (46, 75, 90, 91, 137, 154,			161.8		0	34.75	2	6
4 987.0		10	211, 251, 271)			Ir (78, 90, 91, 127, 131, 175.1)			31.35	4	8
16.9		10	$\lambda$	A	S	$\lambda$	A	S	3 675.00	4	4
4 896.7		10	6 900.37	6		7 834.32	5		61.72	5	3
62.3		10	6 891.3		10	7 183.74	5		53.20	1	6
50.4		10	I 47.8	8		7 037.85	4		36.22	6	3
06.5		8	6 197.8		6	6 929.9	5		28.69	7	5
4 763.4	1	10	6 097.0		7	6 893.4	4		17.23	6	4
30.5	1	8	5 819.9	4	10	88.72	4		09.78	6	3
08.0		8	I 5 709.7	5		30.06	4		05.83	2	10
4 675.6		10	5 644.87		10	6 686.08	7		3 573.74	6	6
66.5		10	5 248.6		10	24.74	5		22.05	6	4
40.8		10	4 681.9		10	6 496.9	4		15.96	6	3
32.4	2	10	56.6		10	6 334.45	6		13.67	9	8
4 574.3	1	10	38.9		10	6 288.3	7		3 448.99	7	4
28.1	1	8	I 4 511.31	10R	10	11.33	4		37.05	8	4
12.6	1	8	I 4 101.8	8R	10	6 110.68	8		3 368.50	8	3
4 453.0	2	10	I 3 258.54	6R	3	6 067.85	7		34.19	5	3
34.3	1	10	I 56.06	10R	8R	26.12	5		3 277.28	4	2
10.1	1	10	I 3 039.36	10R	4R	5 894.09	10		66.45	8	3
4 399.0	1	8	08.2		10	87.38	5		41.52	5	3
42.1	1	8	2 983.0		6	82.29	9		29.28	5	3
4 221.1	3	10	41.24		8	73.49	5		20.79	8	5
4 128.7	2	10	I 32.66	6R	4	28.54	7		3 198.93	5	1
3 940.1		10	2 890.23		5	5 778.28	4		68.88	5	3
31.1		10	36.9	8		68.89	4		33.31	6	5
3 897.4	5	10	I 2 753.89	6R	3	36.23	5		20.77	5	3
08.2	5	10	I 13.94	6R	1	09.32	6		00.42	8	3
3 741.9	3	8	I 10.25	10R	3	5 625.55	10		3 042.63	2	6
24.9	3	8	I 2 601.8	4R	1	20.05	6		39.25	5	3
3 688.3	3	8	I 2 560.2	8R	3	5 454.50	10		2 951.23	5	3
86.6	3	8	I 23.9	4R		49.50	10	1	43.17	7	4
3 583.3	3	8	I 21.4	8R	1	5 390.98	7		36.71	5	3
61.2	3	8	I 2 468.0	4R		85.62	7		34.63	6	3
3 498.0	4	8	I 60.1	6R		64.32	10		24.81	8	4
81.8	1	8	I 2 399.2	4R		40.74	8		2 849.74	7	4
61.0	3	8	I 89.6	8R		5 273.77	6		39.18	6	2
3 350.1	2	8	I 40.2	6R		38.92	10		33.23	4	10
42.5	3	8	I 06.1	5	7	5 177.93	8		24.44	6	4
03.0	3	10	2 079.2	4	10	23.66	8		23.18	5	2
3 288.3	10	10	62.7		8	5 046.06	8		2 774.98	2	5
75.0	5	10	1 977.3	2	8	15.00	10		12.72	4	2
3 194.0	10	8	66.7	2	9	02.70	10		2 694.22	6	3
3 081.7	8	5	III 1 749.2	1	12	4 999.72	10		64.77	5	3
77.9		6	III 1 625.6		10	70.46	8		61.99	6	3



Ir.—(Continued)			K.—(Continued)			Kr.—(Continued)			Kr.—(Continued)		
$\lambda$	A	S	$\lambda$	A	S	$\lambda$	G <sub>o</sub>	G <sub>o</sub>	$\lambda$	G <sub>o</sub>	G <sub>o</sub>
2 543.98	5	4	4 309.0		5	7 685.22	7		3 917.6		6
12.57	2	5	4 263.3		8	01.55	10		12.3		5
2 475.11	4	2	25.6		4	7 587.40	10		06.2		8
2 372.78	4	2	23.0		5	6 904.6	5		3 894.7		5
2 221.1		5	4 186.1		10	6 456.3	5		75.4		7
2 092.7		3	49.2		5	6 056.1	2		63.8		5
51.1		5	34.7		5	5 870.917	10		60.4		5
24.4		4	I 4 047.22	10R	10R	5 681.9		5	3 796.9	4	
K (53, 74, 90, 91, 134, 174, 192, 202, 205, 256, 261)			I 44.16	10R	10R	60.1	3		83.2		10
$\lambda$	A	S	01.2		5	33.0		6	78.11		10
I 85 100	1		3 897.9		8	5 570.291	10		54.2		5
I 84 520	1		3 681.5		4	62.2	6		44.8		9
I 74 260	1		18.43		5	19.4	4		41.69		10
I 64 610	1		08.88		5	5 498.0	3		35.8		5
I 310	1		3 530.71		8	4 829.7	3		21.3		7
I 62 360	2		I 3 447.38	6R	2	07.0	4		18.6		8
I 030	2		I 46.37	8R	3	4 765.7		6	18.0		10
I 40 115.5	6		40.4		3	62.45		5	3 690.6		5
I 37 370.7	1		3 385.3		4	38.96		7	86.1		6
I 354.3	4		81.1		4	34.1	4		80.4		7
I 075.6	3		64.7		6	4 694.9		4	79.5	4	
I 36 626.4	3		63.3		8	80.5		4	69.0		9
I 372.7	1		45.7		5	71.23	10		53.96		10
I 31 596.8	4		I 3 217.6	4R	1	58.9		5	31.9		10
I 395	8		I 17.2	6R	1	33.88		5	07.9		9
I 27 215.0	1		I 3 102.2	2R		24.28	10		3 599.9		6
065.6	2		I 02.0	4R	1	19.12		6	89.6		7
I 15 165.8	10		3 062.4		5	15.30		5	35.3		6
I 12 523.0	9		I 34.8	4Rd		4 582.7	4	4	07.4		9
I 434.3	10		I 2 992.2	1Rd	3	77.2		6	03.2		6
I 11 771.73	10		I 63.2	1R		56.6		4	3 488.6		8
I 689.76	10		I 42.7	1R		24.6	4		74.6		7
I 028.0	10		2 550		5	23.1		5	70.0		7
I 9 590	1		2 358		3	02.2	9		60.1		6
I 8 908	1		2 241		5	01.0	7		46.5		7
I 8 500	1		2 190		6	4 489.9		4	39.5		6
7 931			2 078		10	75.0		4	05.1		7
I 7 699.01	10R	5R	1 944		5	63.68	10		3 351.9		6
I 64.94	10R	5R	1 787		4	53.91	10		30.7		7
I 6 939.0	10	6	71		6	36.80		4	25.7		9
I 11.3	10	4	03		9	4 399.9	6		20.3		10
I 5 832.0	7R	4	1 669	4d		76.1	10		11.5		6
I 12.4	6R	3	765.7		3	62.6	9		3 268.5		7
I 01.9	6R	4	612.5		3	55.47		10	64.8		8
I 5 782.6	5R	3	470.4		4	19.58	10		45.7		10
I 5 359.7	5R	2	382.5		2	18.55	8		40.4		6
I 43.2	4R	1	Kr (7, 156, 187, 201, 238)			18.0		5	39.5		6
I 39.9	4R	2	$\lambda$	G <sub>o</sub> *	G <sub>o</sub> *	00.5		5	07.8		8
I 23.4	4R	1	8 928.72	1		4 292.94		6	00.4		6
I 5 112.5	3R	1	8 776.73	3		82.97	4		3 191.2		6
I 5 099.3	3R	1	8 508.85	2		73.97	10		89.1		7
I 97.6	2R		8 298.07	6		4 145.12		6	41.3		6
I 84.3	2R	1	81.02	3		09.2		6	24.4		6
05.58		5	63.22	4		4 098.7		7	3 063.1		5
I 4 965.3	1R		8 190.02	6		88.36		8	46.9		5
I 56.6	1R		12.89	10		65.05		8	2 967.3		5
I 52.0	1R		04.33	7		57.01		8	2 892.2		5
I 42.9	1R	1	8 059.47	4		50.5		5	33.0		6
4 608.43		6	7 854.81	7		44.6		5	16.5		6
4 505.34		5	7 694.53	8		3 997.9		5	2 795.8		5
4 466.66		4				94.8		6	12.4		8
4 388.13		5				54.7		5	2 681.2		4
						20.4		8	48.2		4

\* G<sub>o</sub> = with condenser (Leyden jar);  
G<sub>o</sub> = without condenser.



INTERNATIONAL CRITICAL TABLES

Kr.—(Continued)			La.—(Continued)			La.—(Continued)			La.—(Continued)		
λ	G <sub>o</sub>	G <sub>o</sub>	λ	A	S	λ	A	S	λ	A	S
2 639.8		4	6 753.07	4		4 921.80	7	5	3 929.21	8	10
20.4		4	09.51	4		20.98	7	5	21.54	7	10
2 592.5		5	6 671.41	4	2	4 899.92	7	4	16.03	7	10
06.6		9	61.41	4	1	60.90	6	3	3 886.34	7	10
2 478.9		4	50.81	4		24.06	6	4	71.63	8	10
64.8		8	16.60	4		09.00	6	3	49.00	6	10
59.6		7	6 578.54	5	3	4 748.72	6	5	40.70	5	5
57.7		8	43.17	8	1	43.08	8	10	3 794.76	8	10
56.1		8	26.98	8	4	40.27	8	5	90.82	8	10
53.3		6	6 456.00	5R	3	28.41	7	3	59.07	8	10
52.3		6	54.53	6	1	4 692.49	5	5	15.52	5	4
46.5		8	11.00	10	3	71.81	4	5	13.55	5	6
42.6		7	6 399.04	5	5	68.90	5	8	3 650.17	5	4
39.2		8	94.24	6R	6	63.76	5	8	45.41	6	8
28.3		10	90.48	5R	7	62.51	6	4	3 517.1		10
26.4		9	25.93	5R	1	55.49	7	10	3 380.91	8	10
20.2		10	20.39	5R	5	19.83	5	6	44.56	8	7
18.2		10	6 296.11	5R	5	13.38	6	5	37.49	8	10
15.0		9	93.60	4R	2	4 580.06	6	3	03.11	6	5
13.9		9	66.06	4R	1	74.85	8	5	3 265.65	6	4
09.1		8	62.29	5R	6	70.02	6	1	49.35	5	3
08.5		7	49.94	7R	5	67.90	6	1	45.12	6	4
06.3		6	6 165.73	5R		58.45	7	5	3 171.7		10
2 398.3		10	34.42	5R		49.50	6	1	2 808.36	5	3
94.0		8	29.57	5R	3	26.11	8	8	2 651.7		8
92.8		7	26.09	4R	3	25.29	6	8	10.34	4	5
75.6		10	11.74	4R		22.38	9	10	2 476.7		7
71.5		8	08.49	5R		4 452.17	6	1	2 379.4		10
62.9		8	6 068.74	4R		29.90	10	10	2 297.8		7
59.9		10	38.59	4R		27.56	7	8			
44.5		8	5 930.59	6R	3	4 385.18	5	4			
29.2		8	5 894.83	4R		83.45	6	8			
20.8		6	80.63	5R	2	78.09	7	4			
16.2		10	63.70	5R	2	54.39	8	10			
15.4		9	55.59	4R		34.97	6	8			
14.1		8	48.36	4R		33.80	10	10			
11.9		8	45.03	4R		22.53	6	5			
01.6		8	29.73	4R		4 296.06	9	8			
00.3		8	23.83	4R		86.95	8	10			
2 287.7		10	21.99	6R	1	75.64	4	4			
82.8		10	08.32	5R	1	69.49	6	10			
77.4		7	05.76	5R	2	63.59	6	8			
73.1		6	5 797.59	7R	2	49.99	5	6			
45.3		6	91.33	7R	1	38.39	10	10			
37.0		5	89.23	6R	1	30.95	4	6			
27.9		6	69.97	5R		17.55	6	10			
			69.35	7R	1	04.04	5	4			
			69.07	7R	3	4 196.55	10	10			
			61.84	5R	1	92.34	7	8			
			44.41	5R		52.78	4	5			
			40.65	6R	1	51.97	8	10			
			5 648.25	5		41.75	10	10			
			5 588.34	4R		23.23	10	10			
			41.26	4R		4 099.55	7	10			
			01.35	6R	1	86.71	10	10			
			5 464.39	5	1	77.35	10	10			
			55.14	6	1	67.39	6	8			
			5 301.96	5	1	50.09	6	10			
			5 183.41	8	5	42.92	8	10			
			22.96	5	3	31.70	7	10			
			14.54	6	3	25.87	6	4			
			06.22	6	1	3 995.75	10	5			
			4 999.46	6	3	88.52	10	10			
			86.83	6	2	49.10	10	10			

La (61, 74, 77, 78, 90, 91, 145, 229, 286)

λ	A	S
8 748.42	2	
8 674.38	3	
8 545.43	3	
8 346.55	3	
24.69	3	
7 483.48	4	
7 345.34	4	
34.17	5	
7 282.33	5	
7 161.22	4	
7 068.34	4	
66.21	5	
6 925.26	3	
6 774.28	6	3

Li (61, 90, 91, 123, 134, 174, 205)

λ	A	S
I 74 360	1	
I 40 475	1	
26 891	1	
I 875	2	
I 24 467	8	
23 991	2	
I 19 290	1	
18 697	5	
I 17 552	2	
13 566	2	
I 12 782	2	
I 232	1	
I 8 126.4	10	
I 6 707.86	10R	10R
I 6 240.6	1	
I 6 103.6	10R	10
I 4 971.9	7	4
I 4 636	3	
I 03.0	9R	10
I 02.0	9R	10
I 4 273.3	5	2
I 4 148		
I 32.3	5	1
I 3 985.7	3	
I 15	2R	1
I 3 794	5	
I 19	3	
I 3 232.7	8R	3R
I 2 741.3	6R	2R



Li.—(Continued)			Lu.—(Continued)			Mg.—(Continued)			Mn.—(Continued)		
$\lambda$	A	S	$\lambda$	A	S	$\lambda$	A	S	$\lambda$	A	S
I 2 562.5	5R		3 081.48	9	3	II 3 848.2		7	15 263	10	
I 2 475	4R		77.62	10	10	I 38.29	10R	10R	218	8	
25.6	3R		57.96		10	I 32.17	10R	10R	14 970	3	
I 2 394.4	1R		56.74	10	10	I 29.36	8R	10R	I 13 997	10	
Lu* (65, 76, 90, 91, 130)			20.56	4	10	II 3 538.8		6	I 864	10	
$\lambda$	A	S	2 969.81	6	10	II 35.0		5	685	8	
7 125.85	7		63.33	7	10	I 3 336.69	10	8	I 626	10	
7 031.18	4		51.68	3	8	I 32.17	10	5	500	10	
6 917.28	7		11.40	10	10	I 29.94	8	3	416	8	
6 793.80	5		00.32	10	10	II 3 104.8		10	I 318	3	
6 523.16	10		2 894.86	10	10	II 04.7		10	I 294	5	
6 463.16	10	3	47.50	5	10	I 3 096.92	10R	2	12 976	4	
6 345.44	7		2 796.64	4	10	I 93.05	8R	2	I 900	8	
6 242.42	7	1	72.60		10	I 91.09	8R	1	307?		
35.39	5	1	54.19	4	10	I 2 942.06	6	2	11 782	6	
21.88	10	4	2 657.83	4	10	I 38.5	5		614	4	
6 199.73	5		15.42	10	10	I 36.8	4		378	2	
60.00	6	1	03.32		10	II 36.6	4	10R	I 8 740.9	3	
6 055.05	6		2 578.79	4	5	II 28.7	3	10	I 03.7	3	
04.54	10	1	Mg (47, 72, 90, 91, 97, 98, 100, 111, 132, 158, 174, 198, 203)			15.5	3	8	I 8 672.1	2	
5 984.11	10	1	$\lambda$	A	S	I 2 852.130	10R	10R	I 70.8	2	
83.65	10	1	I 23 991	1		I 48.42	5	1	54.6	2	
5 775.39	6		I 977	1		I 46.78	4	1	8 212.4	2	
36.54	10	1	I 963	1		II 02.712	10R	10R	7 942.9	2	
5 476.70	10	10	I 17 108	6		II 2 798.0		10	7 821.3	2	
02.57	10	1	I 15 768	4		II 95.540	10R	10R	7 764.8	5	
5 135.11	10	1	I 759	1		II 90.83	4	10R	12.4	5	
5 001.14	6	1	I 028	6		82.988	6R	6R	10.2	5	
4 994.13	10	3	I 14 877	10		I 81.43	6R	6R	7 680.20	5	
04.87	5	1	I 12 083	5		I 79.85	8R	8R	46.34	3	
4 839.52	4	1	I 11 828	10		I 78.29	6R	6R	7 326.55	7	
4 785.45	5	3	054?	2		I 76.71	6R	6R	02.92	6	
4 658.00	10	3	I 10 970	3		I 36.6	4	1	7 283.80	6	
4 518.54	10	5	I 963	1		I 33.55	4	1	47.83	5	
4 296.02	5	1	I 813	3		I 2 698.2	5		7 184.29	5	
81.03	5	1	I 9 258	3		I 95.3	4		51.33	8	
4 184.24	10	10	24	1		I 93.8	2		7 069.86	4	
24.73	10	5	I 8 929	2		I 72.6	8		6 989.94	4	
4 054.46	5	2	I 8 806.8	5		I 69.7	6		42.55	5	
3 876.65	10	10	II 7 896.3		5	I 68.2	3		6 605.57	4	
41.15	7	2	II 77.1		4	II 60.82		5	6 491.71	7	
3 684.34	4		I 7 658	2		II 60.76		5	40.97	5	
47.77	5	2	II 6 347.1	4		I 2 026	6	6	6 382.19	3	
36.26	10	3	I 18.5	2		1 931	6		6 078.40	3	
23.97	10	10	I 5 711.13	5	1	1 886	5		I 21.79	10	1
3 567.84	10	5	I 5 528.48	10	5	64	4		I 16.64	10	1
54.43	10	10	I 5 183.602	10R	10	56	5		I 13.50	10	1
44.93	5		I 72.680	10R	10	I 28	3		5 848.97	3	
08.41	10	3	I 67.33	8R	10	II 1 753.6		6	5 780.17	5	
07.40	10	10	II 4 851.1		5	II 50.9		5	38.28	4	
3 472.49	10	10	II 4 739.6		5	44	5		5 567.765	4	1
3 397.02	10	10	I 03.07	10	5	41	5		51.99	5	1
76.54	10	5	I 4 571.12	5	2	II 37	2	7	I 37.748	7	2
59.59	10	5	II 4 481		10	II 35	1	6	I 16.773	8	2
12.12	10	5	II 34.0		8	323.2		4	05.877	6	1
3 281.75	10	5	II 28.9		7	20.9		5	I 5 481.397	6	1
78.96	10	4	II 4 390.6		10	231.6		2	I 70.639	8	2
54.31	10	10	II 84.6		8	Mn (39, 54, 75, 90, 91, 103, 146, 154, 226, 267, 285)			I 32.555	6	1
3 198.13	10	10	I 51.9	8	2	$\lambda$	A	S	I 20.366	7	3
91.78	2	10	I 4 167.6	4	1	17 608	2		13.696	7	2
18.42	7	3	II 3 850.4	6		336	8		I 07.432	7	2
* This list is more or less uncertain. Lutecium = Cassiopeium = *Celtium.						15 965	10		5 399.506	8	3
									94.677	7	2



Mn.—(Continued)			Mn.—(Continued)			Mn.—(Continued)			Mo.—(Continued)		
λ	A	S	λ	A	S	λ	A	S	λ	A	S
5 377.634	8	3	I 3 823.897	4	4	II 2 593.733	4R	10R	5 473.35	6	6
I 41.071	10	8	I 23.512	4R	6	92.95	5	1	I 5 360.59	10	8
5 255.330	5	2	I 09.599	6	6	II 76.12	5R	10R	I 5 240.94	6	3
5 196.603	5	1	I 06.86	6	8	75.51	5	1	I 38.20	7	3
4 965.856	5	1	I 3 610.30	6	3	II 2 452.52	2R	10	I 5 174.15	9	2
I 4 823.523	10	4	I 08.48	6	3	1 993		5	I 72.94	9	1
I 4 783.433	10	4	I 07.520	8	3	52.1		3	4 979.12	5	2
I 66.424	6	3	I 3 586.55	5	5	04		5	4 868.03	5	2
I 65.859	5	2	I 77.881	8R	5	1 892.0		4	30.52	10	4
I 62.375	9	4	I 70.102	4R	3	1 789		10	19.26	10	4
I 61.527	5	2	I 69.799	8R	4	1 573(?)		5	4 760.20	9	9
I 54.048	10	8	I 69.495	6R	5	1 438		5	31.45	10	7
I 39.002	5	2	I 48.187	4R	3	1 118		5	07.25	10	5
I 27.462	7	2	I 48.022	4R	3	13		5	I 4 626.45	10	4
I 09.704	7	2	I 47.792	5R	4	893		10	21.35	7	2
4 626.54	5	2	I 32.11	5R	3	648		2	I 4 595.15	7	2
I 4 502.221	7	4	I 31.999	5R	3	311		1	I 76.49	8	2
I 4 498.900	7	4	I 31.838	4R	2				I 24.34	7	2
I 90.09	5	3	I 3 495.840	5	6				4 491.29	6	2
I 72.80	7	3	I 88.686	4	10				68.27	10	2
I 70.143	7	4	I 82.918	4	10				34.96	10	4
I 64.681	7	5	I 74.139	4	10				II 33.51	1	8
I 62.033	9	8	I 60.330	3	10				11.71	10	8
I 61.092	6	4	I 41.997	5	10				4 381.65	10	8
I 58.265	6	5	3 330.674	4	3				II 77.76	1	10
I 57.554	6	4	20.698	4	1				II 63.65	1	10
I 57.041	5	2	17.30	Gu	1				26.14	9	4
I 55.823	5	3	I 3 258.420	4	2				I 4 293.89	9	3
I 55.320	6	3	I 56.141	4	2				I 93.24	10	4
I 55.019	6	3	I 48.521	4	3				I 92.21	9	4
I 53.012	5	3	I 43.785	4	2				II 79.03	2	10
I 51.59	9	3	I 36.786	6	3				I 77.26	10	6
I 36.357	7	5	28.099	5	3				76.92	10	5
I 14.87	8	6	I 12.893	6	2				51.86	10R	2
4 374.942	4	2	I 3 178.528	8	1				50.69	1	10
I 4 281.097	5	5	I 48.190	4	1				32.61	10	5
I 65.919	5	5	10.69	5	1				4 188.32	10	5
I 57.668	5	4	I 3 079.63	5	1				85.82	8	4
I 39.729	5	5	I 62.13	4	1				43.56	9	5
I 35.29	8	10	I 54.38	4	2				I 02.16	7	3
I 35.144	8		I 44.570	4	2				4 084.39	8	3
4 189.99	4	4	II 2 949.21	6	10				69.91	9	8
76.60	4	4	I 40.39	6	1				3 961.49	3	10
31.12	4	4	II 39.31	6	10				II 41.50	1	10
I 4 083.638	6	6	II 33.06	6	10				I 02.96	10R	10
I 82.917	6	6	I 25.59	6d	1				I 3 864.12	10R	10
I 79.43	6	5	I 14.61	8d	1				33.76	7	3
I 79.25	6	5	2 889.52	3	10				I 3 798.26	10R	10R
I 55.554	8	8	86.68	2	6				II 02.56	2	8
I 48.760	4	8	79.49	1	5				II 3 692.66	2	9
45.20	4	5	I 01.080	6R	5R				II 88.33	1	10
I 41.366	8R	10	I 2 798.271	6R	5R				51.14	1	8
I 35.730	5R	8	I 94.821	6R	5R				35.15	2	10
I 34.489	8R	10R	11.6		5				14.25	8	3
33.63	3R	3	05.74	2	8				3 524.62	2	7
I 33.074	8R	10R	01.70	3	5				04.41	6	2
I 30.760	6R	10R	2 695.36	1	5				3 447.13	10	3
I 18.105	8	8	72.58	1	5				02.81	1	8
3 985.24	4	3	55.8		5				I 3 384.62	8	2
I 3 843.99	6	4	38.17	1	5				I 58.12	9	2
I 41.09	4	6	32.35	1	8				47.02	6	1
I 39.77	4	5	25.6		8				44.75	8	2
I 34.36	6R	8	18.15	4	8				I 27.30	10	1
I 33.865	6	4	II 05.69	5R	10R				25.67	10	1



Mo.—(Continued)			N.—(Continued)			N.—(Continued)			Na.—(Continued)		
$\lambda$	A	S	$\lambda$	G		$\lambda$	G		$\lambda$	A	S
3 292.32	1	10	I 5 999.46	5		4 171.6	4		I 5 682.8	8	8r
08.85	10	2	II 41.9	7		I 51.44	9		I 75.8		8
I 3 193.98	10R	2	I 31.9	4		45.8	4		I 4 983.2	6r	4r
I 70.35	10R	2	II 5 686.2	5		33.6	3		I 79.0	5r	4
58.16	9R	2	II 79.5	10		I 09.94	10		I 4 752.0	4u	2r
I 32.60	10R	2	II 75.9	5		III 03.4	7		I 48.1	3u	2
21.99	2	10	II 66.5	10		III 4 097.3	10		I 4 669	4r	3u
16.08	1	8	5 543.4	3		II 43.5	3		I 65	3r	3u
3 087.61	2	10	35.2	6		41.3	7		I 4 393	3	1
II 2 923.40	4	10	30.2	4		II 35.0	5		3 711		3
II 11.91	5	10	II 5 495.9	6		26.0	4		3 631		5
03.07	2	10	62.7	3		II 3 995.0	10		3 533.1		8
II 2 871.50	4	10	I 5 328.67	5		II 55.8	7		I 3 302.94	8R	8R
53.19	1	10	5 179.5	4		40.0	3		I 02.34	9R	9R
II 48.21	5	10	II 5 045.0	6		19.0	6		3 285		5
II 16.15	5	10	II 25.6	3		3 870.0	4		3 189		4
2 780.04	3	10	II 15.4	3		II 56.1	3		29		6
75.40	3	10	II 10.6	3		II 42.8	3		3 093		6
II 01.42	2	10	07.4	3		39.0	4		78.5		4
II 2 684.13	3	10	05.1	6		II 30.0	6		56.3		3
72.84	2	10	II 01.34	7		I 22.0	5		2 984.3		4
II 60.58	2	10	4 994.4	4		I 3 650.1	5		80		4
II 44.33	2	10	87.3	4		II 3 437.1	7		51.4		5
II 38.75	3	10	I 35.03	9		II 3 329.2	3		I 2 853.0	4R	5
2 538.46	2	10	I 14.92	4		II 3 006.8	7		I 52.8	5R	5
1.809.8		7	4 895.3	3		I 1 745.31	5		47		4
697		4	III 67.14	4		I 42.81	5		I 2 680.4	3R	4
692		2	III 58.82	3		1 657.2	7		I 80.3	4R	4
548		4	II 10.3	3		1 561.1	7		I 2 593.9	2R	3
377		1	II 03.3	5		I 1 494.78	3		I 93.8	3R	3
			II 4 793.8	3		I 92.83	3		I 43.9	1R	1
			II 88.2	4		1 335.3	10		I 43.8	2R	1
			II 79.8	3		II 1 276.0	10tr		I 12.2	1R	1
			II 74.2	3		V 42.2	4		I 12.1	1R	1
			4 667.2	3		00.4	10		2 493.3		2
			II 54.5	3		1 184.1	10		90.7	1R	2
			II 43.0	9		1 085	10qr		1 787.4		4
			III 40.6	6		III 991.66	3		73.5		6
			III 34.1	6		III 89.90	2		70.8		6
			II 30.5	8		IV 24.31			49.3		8
			II 21.4	7		IV 23.68			03.5		9
			II 13.9	6		IV 23.18			1 698.9?		10
			II 07.1	7		IV 22.57			69.3		4
			II 01.5	7		IV 22.02			68.7		4
			4 552.4	4		II 16.82	2qr		59.7		4
			30.0	6		III 685.5	5qr		376.6?		1
			III 14.8	4					372.3		2
			III 10.8	4							
			I 4 494.68	5							
			I 92.45	5							
			47.0	10							
			32.6	5							
			III 4 379.0	8							
			I 58.29	7							
			I 05.46	6							
			4 241.8	8							
			II 36.9	8							
			II 27.7	4							
			I 23.09	5							
			06.5	4							
			00.0	5							
			III 4 195.7	3							
			79.7	3							
			76.1	5							

N (32, 34, 49, 91, 95, 99, 141, 142, 162, 188, 191, 199, 219, 255)

Na (61, 81, 90, 91, 134, 174, 192, 202, 205, 256, 261, 288)

Nb, see Cb

Nd (11, 62, 78, 90, 91)



INTERNATIONAL CRITICAL TABLES

Nd.—(Continued)			Nd.—(Continued)			Ne.—(Continued)		Ne.—(Continued)	
λ	A	S	λ	A	S	λ	G	λ	G
7 529.03	4		4 232.40	8	5	8 236.42	7	5 881.895	10
13.77	4		4 178.68	6	3	8 136.41	4	72.84	9
11.15	4		77.34	9	10	8 082.46	8	72.17	5
7 448.73	4		56.16	10	10	7 943.19	8	68.4	5
18.18	4		35.33	9	7	7 544.052	8	52.488	10
7 189.41	4		09.47	9	8	35.784	8	28.91	6
29.36	4		09.09	8	6	7 488.887	5	20.17	9
7 066.90	4		4 075.24	7	2	72.455	6	11.42	7
37.34	4		69.26	5	4	38.89	8	04.45	9
6 846.74	5		61.09	10	10	7 245.165	10	04.10	6
03.98	4		21.76	7	3	7 173.938	10	5 764.42	9
6 790.42	4		12.28	9	10	7 059.115	4	48.65	6
40.10	4		3 994.70	8	5	51.30	4	48.29	9
6 655.67	4		90.13	9	6	32.411	6	19.53	6
50.56	4	1	63.12	7	6	24.046	6	19.22	9
30.16	4		51.15	9	8	6 929.466	9	18.90	7
6 485.69	4	1	41.53	7	8	6 717.043	5	5 689.81	7
6 385.18	8	3	05.90	7	4	6 678.276	8	62.55	6
41.48	7	2	00.25	6	6	6 598.953	8	56.66	8
10.48	7	1	3 894.65	6	3	32.883	5	56.03	5
6 178.55	4	1	92.06	6	4	06.528	10	52.57	5
6 073.97	4		90.96	7	4	6 444.70	6	5 563.05	5
71.70	4		90.59	6	4	21.68	5	62.76	8
66.05	4		89.95	6	3	09.71	6	62.44	6
07.63	4		75.85	6	2	02.246	10	33.68	5
5 804.00	5	2	63.37	10	8	01.08	5	5 448.51	6
5 729.28	4		51.73	8	5	6 382.991	10	33.65	7
08.25	5	2	3 780.40	5	3	64.96	5	18.56	6
5 688.49	6	3	35.59	7	5	51.8	5	12.66	7
20.58	8	5	3 653.10	6	2	34.428	9	00.56	10
5 594.40	8	5	09.78	5	1	30.89	6	5 372.31	5
5 485.68	7	4	3 592.58	5	2	28.15	7	60.02	6
31.53	4	3	43.33	5	2	13.65	6	58.02	10
5 361.47	5	4	3 410.21	4	1	04.789	5	55.40	6
19.80	9	4	3 388.01	5	1	6 293.7	5	55.18	6
5 293.17	9	5	28.26	5	2	66.495	10	49.21	6
49.54	7	4	00.14	4	2	58.78	5	43.29	9
5 192.62	6	3	3 275.20	4	2	46.71	5	41.097	10
4 920.66	9	3	17.10	4	1	17.281	9	30.78	10
4 859.01	5	5	3 133.56	4	2	13.88	6	26.41	5
25.47	8	8	3 092.91	4	2	05.76	5	01.77	5
11.33	5	5	Ne (7, 41, 44, 180, 181, 194, 209, 220, 275, 277)			6 182.15	5	5 298.20	6
4 706.54	7	4	λ	G		63.594	8	08.87	5
4 634.21	5	3	9 300.70	2		50.27	5	03.90	6
4 579.30	5	4	9 220.28	2		43.062	10	5 193.23	6
63.21	6	5	01.88	2		42.51	5	93.12	6
41.25	5	5	9 148.72	2		28.45	6	88.61	6
01.82	7	5	8 865.72	3		6 096.163	8	51.96	5
4 462.96	10	10	53.97	3		74.338	9	45.01	8
51.55	10	10	8 783.75	4		29.997	7	44.93	8
46.37	10	10	80.63	4		00.95	5	22.34	6
11.03	8	5	8 681.86	3		5 991.68	6	22.25	6
00.84	10	5	79.52	3		87.93	7	16.49	6
4 385.68	10	8	54.380	6		75.534	8	13.66	5
75.00	10	6	34.63	5		74.64	9	5 080.38	6
58.20	9	8	8 591.25	6		65.44	10	37.74	8
51.23	9	8	8 495.37	7		61.63	5	31.34	7
27.93	7	5	18.41	7		44.834	9	05.15	8
25.77	10	5	8 377.62	7		39.32	5	4 994.92	5
14.50	7	8	00.35	7		18.92	7	57.12	5
03.61	10	10	8 266.02	5		13.63	7	57.03	8
4 282.51	10	8	59.36	4		06.44	5	55.38	5
47.37	10	8				02.48	5	4 892.08	7



Ne.—(Continued)		Ne.—(Continued)		Ni.—(Continued)			Ni.—(Continued)			
λ	G	λ	G	λ	A	S	λ	A	S	
4 884.91	8	3 454.195	6	I 7 727.68	10		5 176.55	6	1	
37.31	7	47.703	7	I 15.64	7		I 68.66	8	1	
27.59	6	17.903	8	I 14.27	8		I 55.76	9	1	
27.34	8	3 369.905	10	I 7 619.24	9		I 46.48	10	2	
21.93	6	69.81	8	I 17.02	10		I 42.76	10	2	
18.79	5	55.2	6	I 7 574.10	7		I 37.09	8	1	
17.64	6	35.1	7	I 55.67	9		I 29.38	8	1	
10.07	5	3 148.60	5	I 25.18	8		I 25.20	7		
4 790.22	8	26.19	6	I 22.87	8		I 15.42	9	2	
88.93	10	3 079.18	5	I 7 481.49	5		I 5 099.97	7	1	
80.34	6	78.87	5	I 22.34	9		84.07	6	1	
58.72	5	76.97	6	I 14.51	6		81.12	9	3	
52.73	8	63.69	6	I 09.35	9		80.53	8	3	
49.56	6	57.39	7	I 7 393.67	10		I 35.36	10	3	
15.34	10	2 992.44	6	86.24	7		I 17.59	7	2	
12.06	8	92.42	6	85.23	7		I 4 984.12	9	2	
10.06	8	82.66	7	I 7 291.30	8		80.17	9	2	
08.86	10	74.71	7	I 61.94	8		04.42	9	3	
04.39	10	47.30	6	I 7 197.07	4		I 4 866.28	7	2	
02.53	5	32.72	5	I 82.06	9		I 55.42	8	3	
4 679.13	5	13.17	6	I 22.29	10		I 31.19	5	3	
78.21	6	2 872.66	5	I 7 024.76	8		I 29.03	8	3	
61.09	5	2 795.10	5	I 6 914.58	7		I 4 786.542	10	3	
56.38	6	2 675.64	6	I 6 842.08	6		I 56.526	7	3	
45.41	6	75.24	6	I 6 772.36	9		I 15.757	8	3	
28.30	7	51.01	6	I 67.79	10		I 14.420	10	8	
09.91	7	47.42	8	I 6 643.66	10	1	I 4 686.21	5	3	
4 582.45	5	45.70	5	35.14	6		I 48.655	10	3	
82.05	5	45.51	6	I 6 598.54	6		I 04.991	9	3	
75.86	10	2 595.21	6	I 8° 33	6		I 00.366	8	1	
75.06	6	Ni (8, 12, 54, 75, 87, 90, 91, 109, 114, 177, 193, 212, 216, 226)			I 6 482.84	7	1	I 4 592.535	9	4
40.38	8				21.47	7		I 4 470.484	9	3
38.31	6				I 6 384.69	7		I 62.462	8	3
37.76	10				I 78.22	7		I 59.044	9	8
37.68	6	λ	A		I 39.17	10		I 01.551	10	8
36.31	5	18 040	2		I 14.66	10		I 3 858.33	10	8
4 488.09	6	17 986	2		I 6 256.39	7	1	I 31.690	6	2
83.19	5	16 999	6		I 23.97	6		I 07.14	8	8
25.42	5	868	2		I 6 191.23	7	1	I 3 783.53	8	5
24.81	6	495	2		I 86.77	7		I 75.57	8	5
22.52	6	409?	5		76.80	10	2	I 36.812	6	3
3 727.3	6	363	10		I 75.44	10	1	I 22.48	6	1
13.3	9	313	2		63.36	8	1	I 3 674.13	6	3
01.22	7	14 874	3		I 16.16	9	1	I 19.392	10	10
3 694.4	9	102	2		I 08.14	7	1	I 10.47	9	4
85.73	7	13 969	2		I 6 086.34	10	1	I 3 597.700	8R	6
82.23	7	829	3		I 5 892.882	9	1	I 71.872	7R	3
64.3	7	722	5		I 57.759	10	1	I 66.375	10R	10
33.660	6	553	2		31.60	8		I 24.539	10R	10
09.17	5	11 591	3		I 05.20	10		I 15.056	9R	10
00.16	6	198	4		I 5 760.84	6	1	I 10.339	7R	10
3 593.632	7	10 980	5		I 54.67	6	1	00.852	6	4
93.522	8	378	4		I 15.09	8	1	I 3 492.962	10R	10
74.9	6	330	3		I 09.55	8	2	I 83.781	6R	4
68.7	8	301	3		5 694.97	7	1	I 72.55	7R	5
20.470	10	195	5		82.20	7	1	I 61.661	10R	10
15.189	6	I 9 519.99	2		25.28	7	1	I 58.467	10R	10
01.214	6	9 106.33	3		I 14.79	6	1	I 52.891	6R	5
3 498.063	5	I 8 862.60	4		I 5 593.74	6	1	I 46.262	10R	10
72.573	8	I 7 917.47	7		I 92.24	7	2	I 37.281	6R	5
66.578	6	I 7 863.70	5		I 5 476.91	10	10	I 33.57	9R	6
64.337	5	I 7 797.66	8		I 35.87	7	1	I 23.710	8R	5
60.524	5	I 88.95	6		11.20	6	1	I 14.77	10R	10
		48.94	10							



Ni.—(Continued)			Nt, see Rn		O.—(Continued)		O.—(Continued)	
$\lambda$	A	S	O* (26, 49, 52, 121, 140, 141, 161, 202, 240, 255)		$\lambda$	A	$\lambda$	S
I 3 413.940	3R	2	I 13 163	1	I 1 027.5	8	4 072.156	10
I 13.480	5R	3	I 11 300	2	I 25.8	9	69.903	9
I 3 392.992	10R	8	I 294	2	I 978.6	4	3 982.725	6
I 91.051	7R	4	I 287	4	I 78.0	5	73.266	7
I 80.883	4R	2	I 9 263.9	7	I 76.5	5	54.368	7
I 80.577	10R	6	I 8 446.77		I 73.9	4	45.033	5
I 74.224	4R	2	I 46.37		I 73.3	5	11.951	5
I 71.993	5R	3	I 7 775.42	6	I 71.8	8	3 882.2	5
I 69.57	10R	4	I 74.20	8	I 53.0	2	3 759.86	5
I 66.170	5R	3	I 71.97	10	I 52.4	4	54.72	4
I 65.771	4R	3	I 7 002.22	4	I 50.9	4	27.36	5
I 61.558	5R	3	I 6 456.08	9	I 50.2	4	12.7	4
I 20.259	5R	3	I 54.55	7	I 48.7	4	2 881.5	8
I 15.669	7R	3	I 53.69	6	$\lambda$	S	2.631.3	4
I 3 243.064	8R	3	I 6 158.21	10	I? 7 952.3	5	2 528.6	5
I 34.656	5R	2	I 56.78	8	I? 50.8	5	24.1	4
I 32.944	8R	3	I 55.99	7	I? 47.7	6	16.1	7
I 25.030	5R	2	I 6 046.34	7	7 157.3	10	14.3	4
I 21.660	4R	2	I 5 958.53	6	6 654.7	4	06.8	5
I 3 197.120	5	2	I 50.60	5	41.3	4	2 478.5	6
I 34.104	10R	4	I 5 436.83	8	6 549	5	35.2	6
I 01.880	9R	3	I 35.76	6	6 265	5	II 2 182.72	4
I 01.561	9R	4	I 35.16	5	6 115	5	II 1 961.60	3tr
I 3 097.121	5	2	I 5 330.65	10	05	5	1 787.0	7
I 80.757	6	2	I 29.58	7	4 943.2	6	81.4	7
I 64.625	6	2	I 28.97	6	41.0	4	60.9	8
I 57.648	10R	4	I 5 299.00	5	II 24.60	6	43.1	5
I 54.318	8R	4	I 5 146.06	5	II 06.88	5	1 277	5
I 50.825	10R	6	I 5 020.13	5	4 857.0	4	47.7	10tr
I 37.939	9R	4	I 19.34	4	4 751.5	4	17.62	10
I 12.007	9R	5	I 18.78	3	05.2	6	00	10tr
I 03.627	9R	4	I 4 968.76	6	4 699.0	5	1 175.6	10
I 02.491	10R	5	I 67.86	5	76.246	5	52.6	6
I 2 994.46	7R	3	I 67.40	4	61.650	5	34.8	10d
I 92.599	6	2	I 4 803.00	4	50.853	5	32.3	10
I 81.652	7	3	I 4 773.36	5	49.148	9	28.4	5
I 43.922	6	2	I 72.89	4	41.827	8	1 085.2	10
I 2 821.296	4	2	I 72.54	3	38.865	5	66.3	5
I 2 798.66	4	1	I 4 655.36	4	4 596.189	7	41.71	7
2 545.92	1	6	I 4 368.30	10	90.983	8	41.00	8
10.89	4	10	I 4 233.32	7	4 448.3	4	39.26	8
2 437.90	1	10	I 22.78	5	16.974	9	36.9	7
16.14	1	10	I 17.09	4	14.888	10	26.0	5
2 394.56	2	10	I 3 947.58	4	4 366.906	6	10.5	10
75.43	1	8	I 47.48	7	51.275	7	991.5	10d
I 45.53	2R	8R	I 47.29	10	49.435	7	90	10d
I 25.81	3R	2	I 3 825.07	6	47.429	5	78.62	4
I 20.08	5R	1	I 23.56	7	45.570	6	78.00	5
I 12.36	3R	1	I 3 692.44	7	19.647	6	76.50	5
I 10.99	3R	2	I 2 883.84	6	17.160	6	73.92	4
2 029.1		6	I 1 358.7	5	4 254.1	4	73.26	5
21.0		6	I 55.7	8	4 189.793	8	71.76	8
19.0		6	I 06.1	10	85.453	8	17.8	15
1 979.3		6	I 05.0	10	53.310	6	16.4	15
29.7		5	I 02.3	10	32.99	5	04.7	10
1 855		5	I 1 041.7	5	20.267	6	889.7	8
1 767		6	I 41.0	8	19.222	8	III 35.288	9
09		6	I 39.3	8	05.001	6	III 35.094	3
1 693		7	I 28.2	7	4 097	4	II 34.462	10
53		6			92.9	4	III 33.741	8
1 527		2			89.3	5	II 33.326	9
1 499		2			85.2	5	III 32.926	7
1 398		2			75.869	10	II 32.756	8

\* Spark spectrum is given after arc.



O.—(Continued)			Os.—(Continued)			P.—(Continued)				Pb.—(Continued)					
	λ	S		λ	A	S		λ	A	S	G		λ	A	S
II	796.605	6		4 260.85	10	5		IV 3 347.7		6	6		5 608.8	4	10
V	62.004	4		4 175.62	7	2		III 3 234.54		6	6		5 005.45	3	2
V	61.131	4		73.24	9	2		III 20.23		6			4 386		10
V	60.457	5		72.55	6	1		V 3 176.06		5	5		4 245.2		10
V	60.232	3		35.80	10	5		III 2 896.17		5	5		42.5		10
V	59.453	4		12.03	10	4		III 84.75		5			4 168.04	3	10
V	58.685	4		4 091.83	9	2		IV 2 739.3		2	5		4 062.15	3	10
II	18.567	7		66.71	10	3		IV 25.67		4	4		57.830	5R	10R
II	18.495	7		3 977.24	10	3		2 644.2		1	5		19.64	3	10
III	03.853	7		63.63	10	3		I 2 554.95	3	4	1		3 854.0		10
III	02.898	6		3 876.80	7	3		I 53.31	3	5			3 739.950	5R	4R
III	02.817	6		57.09	10			I 35.62	4	5			3 683.472	3R	10R
III	02.327	6		49.96	10			I 33.98	2	4			39.584	6R	10R
II	673.752	5		40.29	10	1		I 2 154.77	7		7		3 572.739	5R	10
II	72.913	5		36.03	10	2		I 53.63	6		6		3 176.5		10
II	44.159	6		3 793.90	10	3		I 49.81	8		8		37.8		10
II	17.064	5		90.12	9	3		I 36.79	8		8		3 043.87	1	10
II	16.309	5		82.20	10	4		I 36.10	6		6		2 873.32	6R	10R
	580.975	4		52.7	10	7		I 2 034.02	7		7		33.07	6R	10R
	80.409	3		20.13	10	2		I 32.98	6		6		23.20	4R	10R
IV	55.23			19.50	10	2		I 24.98	6		6		02.007	5R	10R
IV	54.52			3 670.90	7	2		I 23.98	7		7		2 663.17	10R	10R
IV	54.07	5		56.90	7	1		I 1 859.36	6		6		14.203	6R	5R
IV	53.33			3 598.11	9	2		I 58.85	8		8		13.68	3R	3R
III	25.79	6		60.88	9	4		I 51.11	6		6		2 577.280	6R	3R
III	08.180	6		59.82	9	3		I 46.8			7		2 476.39	4R	2R
III	07.684	5		28.60	9	3		34.5			4		46.20	4R	4
III	07.384	4		3 370.60	7	2		1 787.5			6		43.86	4R	4
	374.3	4		01.56	9	2		82.7			7		11.75	4R	2
	05.7	3		3 267.94	8	3		74.8			7		01.94	4R	3
	136.6	0		32.05	6	3		1 693.8			4		2 393.81	5R	3R
Os (78, 90, 91, 131, 175.1, 232)				3 156.25	7	3		85.8			5		32.47	4R	2
	λ	A	S		3 058.66	7	4	71.5			3		2 246.90	6R	4R
7	852.18	3			2 909.08	7	5	V 1 128.039		10			37.42	3R	2R
7	602.96	6		P (29, 30, 31, 32, 90, 91, 105, 248, 249)				V 18.015		10			03.5	3	4R
7	407.97	4						IV 1 035.54		4			2 175.6	4R	
7	253.52	5						III 03.64		5			70.0	6R	2R
7	148.89	6						III 998.03		5			59.6	3R	
45.50	8							III 21.86		5			15.0	5R	
7 060.62	6							III 18.69		5			2 088.2	5R	
6 955.96	8							III 17.14		5			60	7R	7
6 806.61	7							III 13.99		4			59	7R	10
6 729.54	9							V 871.420		5			1 869		5
6 576.81	6							V 65.475		4			22	8	3
6 403.18	8							III 59.69		6			1 796.5	6	3
6 227.74	10							IV 27.95		6			81		2
5 995.99	10							IV 24.76		6			26	6	2
5 857.57	10							IV 23.21		5			1 682.5	6	2
5 780.81	10							Pb (46, 59, 62, 74, 75, 90, 91, 133, 150, 154, 172, 223, 276)				71		2	
21.94	10								λ	A	S		60		2
5 584.43	10												1 554		10
23.56	10								15 315	3			34		7
5 416.33	10								14 744	3			1 434		10
5 149.73	7								13 102	4			1 349		3
4 865.61	10								12 564	4			16		10
4 794.00	10	3							10 971	3			1 267		7
4 631.83	10	2							888	1			50		10
16.78	10	2							651	6			32		7
4 550.40	6	3							500	10			13		3
4 420.46	10	10							291	10			03		7
4 394.87	8	3							7 228.98	6			1 166		7
11.39	10	3							6 002	5			1 029		10
4 293.95	8	3							5 895.7	5			04		3



Pb.—(Continued)			Pd.—(Continued)			Pr.—(Continued)			Pt.—(Continued)		
$\lambda$	A	S	$\lambda$	A	S	$\lambda$	A	S	$\lambda$	A	S
954		3	2 776.87		10	4 783.39	4	1	6 326.6	10	1
927		7	I 63.09	8R	6	36.72	4	2	5 840.13	4	1
907		7	2 658.74	2	10	4 628.74	4	3	5 478.50	10	2
894		5	35.92	2	10	4 563.13	5	3	75.78	10	2
890		3	II 28.24	1	10	34.15	6	4	5 368.99	10	1
884		5	II 2 565.51	1	10	17.58	6	2	01.02	10	5
			51.78	1	10	10.15	10	10	5 227.64	10	2
			II 05.72	2	10	4 496.43	10	10	5 059.48	10	3
			2 498.79	3	10	68.67	9	8	4 684.09	5	1
			88.92	4	10	49.84	8	4	57.95	6	3
			86.53	1	10	29.23	10	10	4 552.41	10	10
			I 76.43	10R	2	08.83	10	10	20.90	10	4
			I 47.92	10R	8	05.84	8	5	4 498.75	10	10
			46.18	1	10	4 368.33	9	8	42.55	10	5
			II 33.11	2	10	33.98	10	8	4 327.07	6	3
			I 26.87	1	10	05.80	10	10	4 118.69	10	10
			18.73	1	10	4 297.75	8	5	3 922.98	8	10
			2 372.16	2	10	80.09	8	4	3 672.00	8	3
			II 67.96	1	10	72.27	9	5	28.11	10	4
			II 1 781.8		6	41.03	10	10	3 485.27	8	3
			II 41.0		6	25.34	10	10	08.14	8	8
			II 04.3		8	23.00	10	10	3 301.87	10	5
			II 1 693.4		6	06.72	10	10	3 204.05	9	4
			II 67.6		7	4 189.52	10	10	00.72	7	3
			II 25.8		5	79.43	10	10	3 156.56	8	3
			II 1 596.8		5	64.19	10	10	39.37	8	3
						43.14	10	10	3 064.71	6R	10
						41.26	10	6	42.62	4R	4
						18.49	10	10	2 997.96	7R	10
						00.75	10	10	29.79	8R	4
						4 062.83	10	8	2 893.87	6	3
						56.54	9	8	30.29	8R	5
						54.87	9	6	2 794.21	5R	6
						08.73	10	8	71.67	4R	2
						3 994.81	10	5	33.94	8R	6
						89.70	10	5	19.02	5R	4
						82.06	9	6	05.89	5R	5
						72.15	8	3	02.40	6R	6
						64.82	9	4	2 659.44	10R	10
						47.63	9	4	50.86	4R	4
						18.85	7	5	46.89	6R	4
						08.13	10	8	28.05	7R	5
						08.05	7	4	2 487.18	4R	2
						3 877.22	10	10	67.44	6R	2
						16.10	9	8	28.05	8R	2
						00.31	5	4	24.90	1	10
						3 762.35	4	1	2 357.10	4R	2
						39.19	4	3	10.97	3	5
						3 687.05	4	3	2 288.19	6	3
						45.66	3	1	1 928.5		5
						3 355.66	3	1	1 889		5
						2 985.77		8	1 723		4
						80.51		8	1 680		5
						2 488.75		5	1 597		3
									1 473		4
									61		4
									1 287		5
									26		5
									13		3
									1 199		3
									18		3
									1 056		3
									935		3
									930		3

Pd (55, 78, 90, 91, 127, 131, 175.1)			Pr (11, 62, 78, 90, 91)			Pt (24, 78, 90, 91, 127, 131, 154, 175.1, 266)		
$\lambda$	A	S	$\lambda$	A	S	$\lambda$	A	S
I 8 132.85	6		7 721.82	3		8 224.79	6	
I 7 915.89	7		7 645.68	3		7 217.58	6	
I 7 763.99	10		7 451.72	4		7 113.75	10	
I 7 486.93	7		7 114.58	4		6 842.60	8	
I 7 368.14	10		7 021.55	6		6 710.39	10	
7 194.11	6		6 827.70	6		6 523.5	4	
I 6 916.56	9		6 798.69	8				
I 6 833.42	8		47.17	6				
I 6 784.6	10	1	6 673.68	10				
I 74.6	6		56.9	6				
I 6 508.4	6		6 566.8	5				
I 6 130.60	8		6 478.1	5				
I 5 739.66	4		31.9	5				
I 5 695.08	9	1	29.7	5	1			
I 70.04	10	1	6 359.07	5				
I 5 542.79	10	1	6 281.34	5				
I 5 395.26	10		6 161.20	5	2			
5 295.60	10	2	6 055.13	6				
I 5 163.80	10	1	17.82	5	2			
I 4 817.52	9	2	5 939.94	5	2			
I 4 788.20	8	2	5 879.18	6	1			
I 4 473.61	7	4	23.70	6	1			
I 4 212.98	6R	10	15.24	8	1			
I 3 958.65	5R	10	5 707.60	6				
I 3 894.21	6R	10	5 668.46	6				
I 32.32	10	10	05.63	5	2			
I 3 799.20	5R	8	5 509.16	4	2			
I 18.91	4R	10	5 469.88	5				
I 3 690.37	6R	10	5 381.27	4	2			
I 34.68	10R	10	22.77	5	3			
I 09.55	9R	10	5 220.11	5	3			
I 3 571.17	5R	10	5 173.92	6	4			
I 53.09	7R	10	10.79	6	3			
I 16.95	8R	10	10.40	6	2			
I 3 489.78	4R	10						
I 81.16	7R	10						
I 60.75	7R	10						
51.36		10						
I 41.41	6R	10						
I 33.44	5R	10						
I 21.23	8R	10						
I 04.59	10R	10						
I 3 373.00	6R	10						
I 02.14	6R	10						
I 3 258.78	6R	8						
I 51.64	5R	6						
I 42.71	10R	10						
I 3 114.05	5R	8						
I 3 065.31	4R	4						
I 27.92	4R	6						
2 980.66	1	10						
I 22.51	7R	3						
2 854.60	2	10						
2 787.94		10						



Pt.—(Continued)		
$\lambda$	A	S
805		3
714		3
702		3
696		3
390		1

Ra (90, 91, 242)		
$\lambda$	A	S
6 446.1	5	8
6 337.0	1	6
6 200.4	5	10
6 167.2	1	8
5 958.2	1	10
II 5 813.7	3	10
5 660.6	5	10
16.6	1	8
01.5		8
5 501.8	1	8
5 406.6	2	8
00.1	2	8
4 971.7	2	8
4 856.1	5	8
I 25.94	10	10
II 4 682.20	10	10
II 4 533.17	10	10
II 4 436.22	5	10
II 4 340.67	10	10
05	3	7
II 3 814.44	10	10
II 3 649.60	10	10
2 813.73	10	10
2 708.94	8	8

Rb (87.1, 78, 90, 91, 134, 174, 201, 205, 223, 228.1)

$\lambda$	A	S
I 74 280	3	
72 690	2	
I 65 670	2	
I 64 360	2	
I 52 313	2	
I 46 960	8	
I 190	1	
I 39 898	6	
I 827	3	
I 38 511	3	
I 15 290	10	
I 14 754	10	
I 13 667	10	
I 444	10	
I 237	10	
I 10 082	10	
I 7 947.63	8R	
I 7 800.30	10R	
I 7 408.4	10	
I 7 280.2	10	
6 775.1		9
I 6 298.6	10	3
I 06.5	8	2
I 5 724.5	4	2
5 699.2		6
36.0		6
5 522.8		6

Rb.—(Continued)		
$\lambda$	A	S
5 152.1		6
4 885.6		5
4 782.9		7
76.0		9
4 648.6		10
22.4		10
4 571.8		10
30.3		6
4 430.7		10
26.1		10
01.4		10
4 380.7		10
77.1		10
71.8		10
48.3		10
4 293.9		10
73.1		10
44.4		10
I 15.6	10R	9R
I 01.8	10R	9R
4 193.0		10
36.2		10
04.3		10
4 083.9		10
3 978.1		10
40.6		10
3 801.9		10
3 699.6		10
62.7		10
00.7		10
I 3 591.6	4R	4R
I 87.1	4R	4R
31.6		10
3 492.7		10
61.6		10
34.2		8
3 393.1		7
I 50.9	5R	5R
I 48.7	4R	4R
40.6		8
21.5		8
3 271.0		7
I 29.1	2R	2R
I 28.0	2R	2R
3 198.8		8
11.4		6
3 086.9		5
23.7		5
2 956.1		10
2 807.6		6
2 631.8		6
2 561.9		5

Rh (78, 90, 91, 127, 131, 175.1, 233)

$\lambda$	A	S
8 425.51	2	
8 136.20	4	
8 045.40	7	
7 830.05	6	
24.91	10	
7 791.61	9	

Rh.—(Continued)		
$\lambda$	A	S
7 495.22	10	
75.74	10	
7 270.82	10	
7 101.68	10	
6 965.65	10	
6 879.94	10	
6 752.40	10	1
6 630.16	10	
6 519.72	10	
6 414.7	8	1
6 102.72	8	1
5 983.58	8	2
5 831.57	10	1
06.86	10	1
5 686.36	10	1
5 599.43	10	3
44.60	10	1
35.02	10	1
5 424.04	10	2
5 390.43	10	3
79.08	10	3
54.38	10	5
5 193.12	10	3
4 851.62	10	3
4 675.02	10	5
4 528.73	10	5
4 379.93	8	3
74.82	10R	10
4 288.72	10R	8
11.14	10R	10
4 135.29	10R	10
28.90	10R	10
4 097.54	8	4
82.80	10	5
3 958.86	10R	10
34.23	10R	6
3 856.50	10R	10
33.87	10R	10
28.47	10R	10
22.35	10R	10
3 799.31	10R	10
93.22	10R	10
65.08	10R	10
48.22	9	10
00.92	10R	10
3 692.35	10R	10
90.72	10R	10
57.99	10R	10
26.60	10R	10
3 597.15	10R	10
96.19	10R	10
83.10	10R	8
28.03	10R	10
02.53	10R	10
3 478.91	10R	10
74.78	10R	7
70.76	10R	8
62.04	10R	8
34.90	10R	10
3 396.82	10R	10
23.10	10R	10
3 283.56	10R	5
80.54	10R	5
63.14	9	2

Rh.—(Continued)		
$\lambda$	A	S
2 968.67	5	1
2 715.30	2	10
05.62	3	10
2 625.40	2	8
2 520.53	2	10
2 490.76	3	10

Rn\* (234, 235, 243, 279)

$\lambda$	G
7 057	3
6 309	5
5 977	3
45	2
5 716	6
5 582.4	8
5 393	3
5 084.5	10
4 979.0	10
4 817.5	7
4 797	2
68.8	7?
21.7	5
02	5
4 681.0	10
44.4	10
25.7	10
09.7	7
04.6	9
4 578	8
08	6
4 460	7
35	5
4 371.7	5
49.9	10
08	10
4 203.3	10
4 188	4
66.5	10
14.7	6
4 017.9	7
3 981.8	9
71.8	7
57.3	5
3 867.6	3
3 665	5
12	4

\* Radon = (Radium) Emanation  
= Niton.

Ru (78, 90, 91, 127, 131, 175.1, 233)

$\lambda$	A	S
8 710.76	2	
8 264.95	4	
7 924.46	5	
7 881.48	10	
09.18	9	
7 791.87	8	
7 621.52	6	
7 499.78	10	
7 393.92	8	



Ru.—(Continued)			S (29, 30, 31, 32, 84, 91, 183, 227, 239)			S.—(Continued)			Sa.—(Continued)		
λ	A	S	λ	S	G	λ	S	G	λ	A	S
7 238.95	9		I 9 237.71		3	3 993.5		5	4 760.28	5	2
I 7 027.93	10		I 28.17		2	83.7		5	04.42	5	3
6 981.99	10		I 12.80		2	28.5		8	4 676.92	5	4
23.22	10		8 694.3		4	3 838.29	8	8	15.71	5	4
6 824.06	10		8 585.6		6	37.37	4	7	4 595.31	5	5
6 690.0	10		7 696.7		8	3 717.7	5	6	43.95	5	5
I 6 444.81	9		86.1		6	3 497.3	8		19.64	8	5
I 5 921.45	10	1	79.6		4	IV 3 098.36	5		4 467.33	5	10
I 5 814.99	10	1	7 244.8		6	VI 933.418	5		34.34	6	8
I 5 636.24	8	3	I 6 757.2		7	V 854.81	5		24.35	6	10
5 510.72	10	1	I 48.8		6	IV 815.97	5		4 390.86	5	10
I 5 484.33	10	1	I 43.7		5	V 786.51	6		18.95	5	8
54.82	10	1	6 538.1		6	IV 744.92	5		4 280.80	5	4
27.61	10	1	I 6 415.5		4	IV 48.40	5		56.40	5	5
01.00	10	1	I 08.1		3	IV 50.23	5		29.70	6	4
5 361.75	10	1	I 03.5		2	IV 53.75	6		03.03	6	6
I 09.26	10	2	I 6 052.8		7	IV 661.42	6		4 118.57	6	5
I 5 171.03	10	2	I 46.0		6				4 092.29	5	4
I 36.55	10	1	I 42.0		5	Sa (67, 69, 90, 91, 143, 244)			3 986.66	4	2
I 4 869.16	10	3	I 5 706.2		8	λ	A	S	3 745.60	5	3
I 15.50	10	3	I 00.4		7	8 913.66	2		39.16	6	5
I 4 757.85	10	3	I 5 696.8		6	8 859.76	2		24.91	6	
I 09.48	10	5	60.1		6	8 717.89	3		3 661.36	4	4
I 4 584.45	10	8	47.1		8	8 632.83	3		34.27	4	4
I 54.52	10R	10	40.0		8	8 510.92	4		3 592.62	5	5
I 4 460.04	8	8	14.3		5	8 305.79	4		3 408.66	3	3
I 4 372.21	10	10	06.1		8	8 230.34	3		3 365.86	3	3
I 4 297.72	10	10	5 579.1		6	8 161.88	3				
I 12.08	10	8	64.9		8	8 068.47	4				
I 4 199.91	10R	10	09.6		10	7 082.40	5				
I 12.76	9	5	I 07.0		5	39.24	6				
I 4 080.62	10R	10	5 473.6		8	20.47	5				
3 923.48	8	5	53.8		10	6 955.33	5				
I 3 799.34	10R	10	32.8		10	6 861.14	6				
I 98.89	10R	10	28.7		9	6 794.20	5				
I 90.50	10R	10	5 345.7		8	31.86	6				
I 86.04	10R	10	20.7		8	6 679.25	5				
I 42.28	10R	3	5 279.0		6	01.84	5				
I 30.43	9R	8	78.6		5	6 569.34	6	2			
I 28.02	10R	8	78.1		3	6 487.65	4	1			
I 26.93	10R	8	12.6	1	8	26.63	4	1			
I 3 661.35	8R	10	01.0		6	6 256.69	5				
34.94	10R	3	5 032.5		8	6 159.49	4				
I 3 596.17	10R	6	14.0		8	5 965.70	4				
I 93.03	10R	6	09.6		6	38.91	4				
I 3 498.95	10R	8	4 925.3		6	5 874.22	4				
I 36.74	10R	5	4 696.3		6	14.88	5				
28.32	10R	3	95.5		8	5 787.04	5				
17.35	10R	3	94.2		10	73.77	5				
3 339.55	8	2	4 525.0		6	5 696.74	4				
I 3 294.13	8	8	4 362.5		6	44.11	6				
3 177.03	3	8	32.7	1	5	26.01	5				
3 064.83	7	2	4 294.42		8u	5 550.38	6R				
2 976.58	4	10	84.97	5	8	19.64	5				
65.55	3	10	53.60		10	5 498.22	6				
45.67	3	10	4 189.9		5	93.72	6				
16.26	8	3	74.31	1	7	5 341.26	5				
2 875.00	7	2	63	3	10	5 271.38	4	1			
2 734.34	4	10	53.2		8	5 071.20	4	1			
12.40	4	10	45.1	2	10	44.27	4	1			
2 692.1	5	10	42.5	2	8	4 910.41	4	1			
78.73	4	10	4 028.8		6	4 883.78	4	1			
2 402.72	3	10				44.20	4	3			



Sb.—(Continued)			Sb.—(Continued)			Sc.—(Continued)			Se.—(Continued)			
$\lambda$	A	S	$\lambda$	A	S	$\lambda$	A	S	$\lambda$	G	S	A
I 4 033.5	6	4	981		10	II 3 590.50	10	10	5 176.0	9	2	
I 3 722.8	8	5	976		10	II 89.65	10	10	42.1	8	1	
I 3 637.8	9	6	861		6	II 80.96	10	10	5 096.5	8	1	
I 3 504.5	3	10	805		5	II 76.36	10	10	68.6	8	1	
3 498.5		10	723		3	II 72.55	10	10	31.3	8		
73.9		10	691		2	II 67.71	10	10	4 992.9	8	1	
I 3 383.2	5	2	456		1	II 58.55	10	10	75.7	8		
I 3 267.5	8R	10	Sc (78, 90, 91, 96, 123.1, 175.2, 216.1)			35.73	10	10	4 844.8	10	1	
41.2		10				II 3 372.15	10	10	40.5	8	1	
I 32.5	8R	10	$\lambda$	A	S	II 68.95	10	10	4 763.6	8	2	
3 040.7		10	8 241.18	4		II 61.95	10	8	I 42.4	8		
I 29.8	8R	10	8 194.87	4		II 61.29	10	8	I 39.1	9		
2 913.3		5	7 800.44	10		II 59.69	10	8	I 30.9	10		
I 2 877.920	10R	10R	7 741.20	10		53.74	10	10	4 648.4	8	5	
51.1	4	4	7 697.76	10		I 3 273.64	5	2	18.7	8	3	
2 790.4		10	7 136.13	6		I 69.92	5	2	04.3	9	5	
I 69.95	10R	10R	6 835.03	10		3 065.1	10	5	4 563.9	9	4	
27.22	5R	8	29.52	10		52.92	10	4	16.2	8	2	
18.90	3R	10	19.51	10		45.73	10	3	4 467.6	9	3	
2 692.27	3R	3	17.10	10		39.94	10	2	49.2	8	2	
82.77	4R	5	6 737.90	10		I 19.33	10	1	46.0	8		
I 70.67	5R	5	6 604.62	4	1	2 988.95	10	3	01.0	9	3	
52.60	3R	8	6 413.37	10		2 734.10	4	8	4 382.8	10	6	
12.32	3R	8	I 6 305.70	10	1	2 699.12	6	10	20.4	9	3	
I 2 598.076	10R	10R	I 6 258.98	10	1	II 2 560.26	5	6	4 280.3	8	2	
90.29		10	I 10.67	10	1	II 52.39	10	10	4 182	9	10	
I 28.54	6R	10R	I 5 711.75	10	1	2 438.62	5		76	9	10	
2 478.34	2	6	I 00.15	10	1	2 272.9	4		69.0	10	3	
I 45.55	3R	6	I 5 686.86	10	1	2 062		4	08.8	8	3	
26.36	3R	3	I 71.81	10	1	1 993		5	4 083.2	8	3	
2 383.64	3R	4	II 57.90	10	2	1 880		5	46.7	10	3	
73.7	4R	3	5 526.82	10	3	1 603		5	08.1	8	2	
I 11.5	6R	10R	20.50	10	1	1 214		6	3 901.6	8		
06.5	5R	4	5 481.98	10	1	791		5	3 877.3	8	4	
2 179.25	4R	3R	5 349.29	10	1	Se (80, 169, 189)			49.6	8	2	
I 75.9	5R	3R	5 239.82	10	2				00.9	10	8	
2 068.4	4R	1	I 5 081.57	10	2	$\lambda$	G	S	3 738.7	10	10	
54.0		6	31.03	10	4	I 7 061.9	5		11.6	10	6	
39.7		5	I 4 743.82	10	4	I 6 831.0	5		3 637.5	10	10	
23.9		4	4 670.41	9	10	I 6 746.4	6		3 544	10	10	
1 926.6		5	II 4 415.56	10	10	I 6 699.6	6		14	10	8	
1 870.6		10	II 00.40	10	10	I 79.5	5		3 387.2	10	6	
67		8	II 4 374.50	10	10	I 6 325.6	6		79.8	8	3	
10		5	II 25.00	10	10	I 5 961.9	5		23.1	8	3	
1 783		10	II 20.73	10	10	5 866.2	6		3 225.9	8	3	
62		10	II 14.10	10	10	42.6	6		3 185.5	9	3	
31		5	II 4 246.84	10	10	I 5 753.3	7		3 094.3	8	3	
25		6	4 165.21	6		47.6	7		69.9	8	2	
12		6	I 4 082.42	10	3	I 18.1	7		60.8	10		
1 585		8	I 54.55	8	3	5 697.9	8		38.7	8	2	
66.3		8	I 47.82	7	2	23.1	9		2 951.7	10	3	
14		10	I 23.70	10	8	I 17.8	5		14.9	9	3	
1 438		10	I 20.41	10	8	5 591.2	8		2 880.4	8	3	
1 307		10	I 3 996.61	10	2	67.0	9		37.2	8	4	
1 225		10	I 11.81	10	6	22.6	8		2 777.7	9	3	
11		10	I 07.50	10	6	5 455.8	7		67.4	10	3	
05		10	II 3 651.81	10	10	I 5 374.1	10		2 685.9	8	4	
1 193		10	II 45.32	10	10	I 69.9	10		30.9	8	5	
71		10	II 42.80	10	10	I 65.4	8		2 591.4	10	5	
68		10	II 30.76	10	10	05.3	9		2 459.5	7	3	
62		10	II 13.83	10	10	5 271.1	8		2 354.3	5	3	
1 048		10				53.7	7		2 073		3	8
42		10				27.5	9	2	63		8	8
12		10							38		8	2



## INTERNATIONAL CRITICAL TABLES

Se.—(Continued)				Si.—(Continued)				Sn.—(Continued)			Sn.—(Continued)		
$\lambda$	G	S	A	$\lambda$	A	S	G	$\lambda$	A	S	$\lambda$	A	S
1 993			5	II 1 194.89			5	2 785.02	3R	4	784		3
60		10R	10	III 10.47			5	79.81	4R	5	752		3
1 854		7		IV 1 066.3			8	06.50	7R	7R	508		2
Si (73, 79, 90, 91, 94, 154, 160, 161, 168, 217)				IV 818.0			7	2 661.25	5R	4R	502		2
$\lambda$	A	S	G	IV 815.0			7	58.61		10	410		2
II 6 371.359		2	8	IV 749.7			3	2 594.43	4R	3R	392		1
II 47.091		5	10	IV 457.7			3	71.60	5R	5R	Sr (59, 61, 74, 75, 78, 90, 91, 110, 158, 174, 223, 253)		
II 5 978.970			7	IV 361.6			1	46.56	5R	5R	$\lambda$	A	S
II 57.612			5	Sm, see Sa				2 495.72	5R	4R	I 30 665		
III 5 739.762			8	Sn (4, 46, 59, 90, 91, 138, 154, 167, 171, 223, 251, 276, 291)				83.40	5R	4R	482		
I 08.400			5	$\lambda$	A	S		29.505	7R	8R	I 110	5	
II 5 056.020		2	10	13 022	2			21.699	6R	8R	I 29 225	6	
II 41.063		1	8	12 983	5			08.18	4R	3	28 964		
III 4 574.777		1	4	11 934	10			2 354.84	5R	6R	516		
III 67.872		2	7	853	4			34.80	4R	4R	I 27 356	6	
III 52.654		3	9	827	4			17.22	5R	4R	26 947		
II 4 130.884		6	10	740	9			2 286.68	4R	3R	I 915	6	
II 28.053		5	8	672	2			68.92	3R	3R	806		
IV 4 088.863		6	10	618	6			46.05	3R	3R	714		
I 3 905.515	10	5	10	457	6			31.73	4R	2	I 024	6	
II 3 862.592		4	6	279	10			09.63	3R	2R	20 767		
II 56.021		5	8	194	7			94.5	3R	2R	705		
II 53.657		3	3	10 896	4			71.3	3R		I 262	10	
III 06.56		3	5	808	1			51.4	3R	2	17 446		
III 3 796.11		7	4	458	1			48.6	3R	1	170		
III 91.41		6	3	9 852	1			40.6	3R	1	137		
III 3 590.46		2	8	8 852	1			21.2	3R		I 11.242	10	
IV 3 165.72			8	8 552.6	7			13.9	4R	1R	II 10 915	10	
IV 49.56			6	8 114.1	7			00.8	4R		II 328	10	
III 3 093.423			6	6 844.2	2	2		2 096.3	4R		II 038	10	
III 86.225			7	6 579.2		4		91.6	3R	1	7 673.10	6	
I 2 987.647	5	4		6 453.5	3	6		72.9	5R		I 21.53	5	
I 2 881.587	10R	10		6 310.8	4			40	4R		I 7 309.45	7	
I 2 631.28	5	6		6 171.5	4			1 983.4	3R		I 7 232.24	5	
III 2 541.83		10		54.6	5			51.4	3R		I 7 167.30	6	
I 28.516	10R	8		49.6	6			1 899	3	10	I 7 070.15	10R	1
I 24.118	10R	8		6 069.0	7			11		10	I 6 878.37	10	
I 19.212	8R	5		54.9	5			1 757		10	I 6 791.07	6	1
I 16.119	10R	10		37.7	5			1 570		4	6 643.55	5	2
I 14.322	8R	5		5 970.3	5			1 475		6	17.27	6	3
I 06.904	10R	6		5 799.4		10		37.7		10	6 550.27	6	3
I 2 435.159	5R	5		31.70	7	3		10.8		5	46.80	5	2
IV 2 287.08		10		5 589.4		10		1 387.0		5	04.01	8	4
I 16.685	3	3		62.7		10		70		4	6 408.48	9	4
I 2 124.140		6R		5 333		10		47		4	I 6 388.27	6	1
II 2 072.61			10	4 585.6		10		27		7	I. 86.53	7	1
II 71.94			8	24.74	6	16		14.7		10	I 80.74	5	1
I 58.20			5R	3 801.03	9R	8R		1 251		20	I 69.98	4	1
I 1 988.97		5		3 852.3		10		24		10	I 63.95	4	1
1 885		10		30.60	6R	6		1 158		20	5 598.4	6	1
II 17.06			10	3 283.5		10		32		12	I 43.32	5	2
II 08.14			8	62.33	10R	5R		1 089		5	I 40.04	5	2
II 1 711.0			6	3 175.047	10R	9R		86		5	I 34.80	5	2
II 1 533.55			10	3 034.116	9R	8R		62		3	I 21.76	6	3
II 26.38			8	32.78	3R	3		58		3	I 04.19	5	3
III 00.39			5	09.135	9R	8R		44		15	I 5 486.13	5	2
IV 1 402.9			8	2 913.54	6R	4		19		15	I 80.87	7	4
IV 1 393.9			10	2 863.322	8R	8R		956		10	5 256.91	6	3
II 1 265.04			10	50.61	6R	7R		910		3	38.56	6	1
II 60.66			8	39.987	8R	10R		907		3	29.28	5	1
III 06.9			10	13.58	5R	4R		902		15	25.12	5	1
								892		3	22.21	5	1



Sr.—(Continued)			Ta.—(Continued)			Tb.—(Continued)			Tb.—(Continued)		
$\lambda$	A	S	$\lambda$	A	S	$\lambda$	A	S	$\lambda$	A	S
I 5 156.08	5	1	4 936.40	3	1	5 228.11	5		3 413.77	5	4
I 4 967.92	4	1	4 812.74	4	2	5 089.11	5	1	3 324.40	8	5
I 62.25	6R	2	4 740.14	4	2	65.79	5		3 293.08	5	8
I 4 892.01	6	2	4 691.89	3	2	4 993.85	6		74.24	6	
I 76.31	6	1	81.87	5	5	70.99	5		18.95	5	5
I 76.07	6	1	4 574.32	5	3	31.79	6		6 139.65	4	3
I 72.48	6	2	30.82	5	3	15.91	6		3 078.87	4	8
I 55.07	4	1	10.98	8	3	4 881.14	6	2	2 913.28		10
I 32.07	6	3	4 415.73	3	3	75.58	6	1	09.24		10
I 11.86	6R	4	4 279.06	3	2	37.58	6	1	2 891.29		10
I 4 741.91	5	1	05.88	6	2	13.77	6		2 658.91		10
I 22.27	6	3	4 175.22	4	3	4 752.50	10	8	2 539.91		8
I 4 607.342	10R	6R	29.42	5	2	47.79	6		Te (75, 90, 91, 154, 270)		
I 4 438.04	6	3	4 067.91	6	2	39.92	6	1	$\lambda$	A	S
I 4 361.71	4	2	26.95	4	2	34.19	6	1	6 438.0		10
II 05.47	4	4	3 918.51	3	2	16.08	6		5 755.8		8
II 4 215.515	9R	9R	3 642.05	10	2	02.40	8	2	08.1		10
II 4 161.81	4	3	26.61	9	3	4 681.86	8		5 649.3		10
II 4 077.714	10R	10R	07.40	7	2	62.79	6	1	5 449.7		5
I 30.38	5	4	3 566.72	4	1	45.29	9	2	5 045.2		4
I 3 940.80	5	2	11.03	8	2	41.98	8	3	4 866.5		4
II 3 464.47	6	7	3 497.85	5		4 578.68	8	3	3 175.13	9	2
II 3 380.72	5	6	36.00	5	1	63.69	6	1	2 769.65	9	4
I 66.33	5	2	06.94	5	2	11.52	6		2 530.73	7	5
I 51.26	6R	2	3 361.63	5	1	4 493.08	5	2	2 385.78	10R	10R
30.01	4	2	17.91	7	1	36.13	5		83.27	10R	10R
I 22.23	5	1	11.14	9	3	23.11	5	1	2 265.52	5R	3
I 07.54	4	1	3 242.05	4		4 367.31	5	3	59.02	8R	3
I 01.74	5	2	23.83	4	2	56.84	6	2	55.50	5R	3
I 2 569.50	3R		3 170.28	4	1	53.20	6	3	08.88	6	2
I 2 428.11	3R		24.96	4	1	42.53	6	2	2 160.12	6	1
I 2 354.3	1R		03.25	5	1	18.85	6	3	47.33	8	1
II 2 166	1R	1	3 049.54	5	1	13.25	6	1	43.0	9R	1
II 1 778	9		12.53	5	3	4 278.54	10	10	2 081.8	8	
II 69	8		2 965.15	4	4	4 187.16	5		1 826		5
II 1 620	5		33.56	5	2	44.46	5	10	1 461		7
II 1 613	4		2 891.85	4	1	66.22	5	3	1 345		7
			02.07	3	1	61.59	6	2	1 297		5
			2 758.31	3	1	33.07	8	8	91		5
			14.67	3	2	12.85	7	5	23		7
			2 647.46	3	2	05.57	8	10	19		7
						3 981.90	10	10	16		7
						76.86	10	10	1 174		7
						39.54	10	10	67		10
						25.45	10	10	50		5
						3 899.19	8	8	23		7
						74.19	10	10	17		5
						48.76	10	10	07		5
						3 776.50	8	8	1 064		5
						65.14	6	8	07		5
						11.75	10	4	04		5
						03.93	8	8	931		4
						02.85	6	10	928		4
						3 676.35	8	10	813		5
						58.87	8	8	634		1
						50.42	7	8	509		1
						38.45	7	5	Th (78, 90, 91, 157)		
						28.20	8	3	$\lambda$	A	S
						3 568.52	7	5	7 054.8	4	
						61.75	10	10	6 993.1	4	
						09.18	10	10	89.7	4	
						3 454.06	7	4	6 584.0	4	



INTERNATIONAL CRITICAL TABLES

Th.—(Continued)			Th.—(Continued)			TL—(Continued)			TL—(Continued)		
λ	A	S	λ	A	S	λ	A	S	λ	A	S
6 531.3	4		3 538.75	1	10	I 5 565.470	7	8	II 4 337.924	5	10
6 462.64	5	1	11.64	5	6	I 14.540	8	8	I 14.807	7	3
57.26	4		07.57		10	I 14.349	7	8	II 07.89		8
16.10	4		3 469.94	4	5	I 12.531	8	10	I 05.915	10	8
11.91	4		3 392.05	4	5	I 5 488.228	6	3	I 01.084	10	3
6 396.4	4		13.69	1	10	I 77.727	9	4	I 00.555	10	2
76.94	4		00.54	1	10	II 5 336.80	3	10	II 00.058	6	8
58.64	4		3 290.59		10	I 5 297.248	7	3	I 4 298.675	10	4
42.86	4		32.08	1	7	I 83.449	7	3	II 94.108	6	10
6 274.14	4	1	21.27	2	10	II 26.554	3	10	I 90.94	8	2
61.06	4	1	16.58		8	I 10.391	8R	9	II 90.230	4	10
6 120.56	4	1	3 188.22	5	5	I 5 192.970	8R	10	I 89.083	10	4
12.84	4	1	08.26	4	5	II 88.692	4	10	I 87.417	9	4
04.79	4	1	3 097.92		6	I 73.743	7R	7	I 82.714	6	3
6 099.08	4	1	2 978.68		8	I 5 064.66	10	5	I 74.59	10	4
87.28	5	1	2 898.92		6	I 39.960	9	3	II 4 171.92	3	10
15.41	4	1	2 686.17		6	I 38.407	9	8	II 63.656	4	10
5 989.02	7	2	2 512.72		8	I 36.471	9	8	I 4 078.478	6	4
14.38	4	1	2 463.72		7	I 35.912	7	9	I 24.578	7	3
5 870.51	4	1	41.30		9	I 25.582	8	3	I 09.662	7	4
15.38	4		31.74		7	I 24.850	9	3	I 3 998.643	10	6
5 749.32	4	1	27.98		8	I 22.870	9	5	I 89.764	10	6
07.07	4	1	13.50		6	I 20.027	8	5	I 64.274	7	3
5 639.71	5	1	Ti (9, 37, 38, 75, 78, 88, 90, 91, 92, 146, 154)			I 14.25	10	9	I 62.859	7	3
04.48	4	1	λ	A	S	I 07.214	9	10	I 58.212	10	5
5 539.89	5	2	I 8 518.2	4		I 4 999.511	10	10	I 56.343	10	4
5 462.58	4	1	I 8 435.6	5		I 91.07	9	10	I 48.679	10	4
35.86	4	1	I 26.5	4		I 81.73	9	10	I 47.774	8	3
5 325.10	4	2	I 7 251.7	6		I 4 885.088	8	5	II 13.47	5	10
5 277.45	5	2	I 44.86	5		I 70.138	7	3	II 00.544	5	10
47.65	5	2	I 09.45	8		I 40.882	9	4	I 3 882.88	9	3
5 148.17	4	2	I 6 861.47	5	1	I 20.417	7	3	II 3 761.327	8	10
5 067.97	5		I 6 743.15	5	3	I 4 759.281	8	6	II 59.298	9	10
49.77	7	3	I 6 556.09	6	5	I 58.131	8	5	I 52.866	10	5
28.59	5	2	I 6 303.77	6	3	I 31.172	5R	3	II 41.646	3	10
17.24	8	3	I 6 261.10	9	9	I 4 698.769	8	3	I 41.065	10	2
4 987.16	5	3	I 58.72	9	9	I 91.339	8	4	I 29.812	8R	4
64.15	5	1	I 58.11	9	9	I 81.912	9	6	II 06.22	2	8
19.80	9	6	I 15.26	7	10	I 67.592	10	5	II 3 685.190	10R	10
4 863.17	9	8	I 6 126.22	9	5	I 56.461	8	3	II 62.24	4	10
32.78	5	2	I 6 091.18	7	5	I 23.106	9	3	II 59.77	4	10
18.62	4	4	I 85.24	7	4	II 4 571.98	6	10	I 53.497	10R	4
4 774.27	5	2	I 5 999.666	6	2	II 63.767	4	10	I 42.680	10R	3
61.10	5	3	I 78.535	8	8	I 55.494	9	3	II 41.335	4	10
52.41	6	4	I 65.821	8	10	II 49.63	5	10	I 35.467	9R	3
40.47	6	4	I 53.155	8	10	I 48.772	9	3	II 3 535.41	4	10
4 619.50	7	3	I 41.748	7	4	I 44.696	9	3	II 20.26	3	8
02.88	5	1	I 22.103	7	4	I 36.053	6R	4	II 10.846	8	10
4 510.54	4	5	I 18.542	6	3	I 35.921	6R		II 04.89	7	10
4 391.12	5	10	I 5 899.290	9	10	I 35.576	8R	3	II 3 477.188	9	10
81.89	5	10	I 66.435	9	10	I 34.781	9R	4	II 61.504	9	10
4 208.85	4	8	I 5 766.33	7	3	I 33.249	10R	5	II 56.392	2	9
4 178.04	3	5	I 62.276	7	2	I 27.316	10	4	II 52.476	1	8
16.75	2	6	I 15.124	8	2	I 22.809	9	4	II 44.318	4	10
4 085.05	3	7	I 08.231	5	1	I 18.030	9	4	II 3 394.58	2	10
69.23	3	7	I 02.683	6	2	I 12.74	10	4	II 87.835	8	10
19.14	5	10	I 5 689.475	8	3	II 01.28	5	10	I 85.949	8R	
3 752.58	4	6	I 75.427	7	4	II 4 468.50	6	10	II 83.765	8R	10
41.21	5	6	I 62.92	7	3	I 57.439	9	5	II 80.285	7	10
3 659.51	3	6	I 62.164	7	8	I 55.33	10	4	II 72.80	10	10R
27.40		2R	I 44.137	7	10	II 43.808	6	10	I 71.456	9R	2
17.07	4	5				I 27.106	8	4	I 70.438	9R	2
01.05	3	7				II 4 395.044	7	10	II 61.215	8R	10R



Th.—(Continued)			Th.—(Continued)			Th.—(Continued)			Th.—(Continued)		
$\lambda$	A	S	$\lambda$	A	S	$\lambda$	A	S	$\lambda$	A	S
I 3 354.641	8	3	IV 2 068.8		2	I 2 918.34	10R	1	3 916.50	7	2
II 49.408	9R	10R	1 671.2		10	I 2 826.2	8R		00.83	6	2
II 49.039	6R	8R	58.7		10	I 2 767.89	10R	10	3 847.99	10	10
I 41.874	6R	10R	1 437.3		5	I 10.7	4R	4	38.20	6	4
II 35.192	7	10	III 1 298.8		2	I 09.24	8R	6R	3 761.91	8	7
II 32.108	5	8	III 94.3		2	I 2 609.75	4R		61.33	8	7
II 29.458	6R	10	64.6		5	I 08.98	6R	2	51.82	5	2
II 22.940	8R	10	1 120.5		5	I 2 585.6	4R	1	25.07	5	3
II 3 261.601	4	10	13.4		5	I 80.16	8R	6R	17.91	10R	4
II 48.604	4	10	834.07		2	I 52.9	2R		04.83	5	2
II 41.989	7	10	781.6		10	I 52.5	6R		01.37	9	9
II 39.042	7R	6R	324		1	I 17.44	4R		00.27	10	9
II 36.579	7R	6R	Th (46, 59, 62, 74, 75, 87, 90, 91, 137, 154, 167, 170, 203, 205, 251)			I 2 379.60	8R	10R	3 694.75	5	2
II 34.521	8R	10R				I 16.0	6R	4	78.89	5	3
II 24.24	5	8	$\lambda$	A	S	I 2 237.8	6R	3R	78.18	5	2
II 22.84	7	8	I 71 170	1		I 07.1	4R	2	68.08	6	3
II 17.061	8	8	I 70 230	1		1 893		10	65.79	5	3
II 02.540	6	10	I 55 590	1		28		6	53.62	5	3
I 3 199.924	9R	3	I 51 058	2		15		10	08.77	9	4
I 92.002	9R	1	39 286	6		1 793		9	3 566.47	5	3
II 90.877	7	10	I 246	2		1 660		10	65.90	5	8
I 86.462	9R	3	I 215	2		1 561		8	36.57	5	2
II 68.522	9	10	I 38 131	5		III 59		10	36.20	5	3
II 62.572	9	6	I 35 950	2		1 492		4	35.53	5	3
II 3 088.032	10	10R	I 680	1		78		4	17.62	4	
II 78.646	9	6	I 33 393	1		1 337		4	3 462.21	10	10
II 75.232	9	4	I 27 889	4		III 1 266		8	53.68	10	5
II 72.971	8	3	024	1		1 082		4	41.53	7	6
II 72.106	8	3	I 21 803	3		29		4	29.97	5	4
III 2 984.8		10	397	1		908		2	25.12	7	7
I 67.220	8	2	20 486	1		817		3	3 397.50	6	4
I 56.132	10	2	I 16 340	10		697		4	62.63	7	7
I 48.250	9	2	I 123	10		662		3	02.47	5	3
I, II 41.991	9	4	I 14 598	3		395		1	3 283.40	5	4
I 12.092	8	2	I 593	1		Th* (65, 91)			3 172.82	9	10
II 2 884.102	7	8	I 515	10		$\lambda$	A	S	57.34	6	6
II 41.935	8	4	I 13 014	10		7 731.52	4		51.03	7	9
II 28.067	3	8	I 12 736	10		7 481.08	5		33.87	9	9
II 17.84		10	728	2		6 845.99	8		31.26	10	10
II 10.302	4	10	I 492	2		44.30	8		3 042.36	4	2
II 05.0		10	11 691	1		6 779.77	8		2 640.75	5	1
I 2 758.074	6	1	I 594	8		6 657.72	5		2 509.10	3	2
II 51.7		8	I 513	10		04.95	8		2 480.18	3	
I, II 42.328	7	4	I 482	5		6 460.26	10				
I 2 669.598	6	2	I 10 496	8		5 975.01	5				
I 61.966	5		I 492	5		5 895.63	6				
I 46.638	9	2	I 292	6		38.73	5				
I 44.263	9	3	I 9 513	3		5 764.29	5				
I 41.09	9	2	I 9 171	2		5 631.39	6				
I 19.940	5	1	I 36	2		4 675.27	5				
I 11.28	7R	1	I 8 376	1		4 582.35	6				
I 2 599.914	6	2	6 714	5	2	22.55	5	10			
III 63.4		10	I 6 550	8	3	19.56	6	1			
III 40.0		10	5 948.9	8	8	4 359.93	8	5			
III 27.8		10	I 5 350.47	10R	10	4 242.15	10	8			
II 25.616	4	10	5 153.3		10	06.01	3R	1			
III 16.0		10	4 738.1		10	4 187.61	10R	5			
I 2 418.363	3	1	I 3 775.73	10R	10R	4 094.18	10R	5			
14.0		10	I 3 529.41	8R	10	52.21	8	3			
I 2 384.527	3	1	I 19.22	10R	10R	3 958.08	6	3			
III 75.0		6	I 3 229.76	10R	1	49.27	5	1			
III 46.8		6	I 2 921.53	6R	1	* Thulium = Neothulium.					
2 074.6		2									

U (78, 90, 91, 117, 146, 154, 181)

$\lambda$	A	S
8 691.26	3	
07.92	5	
8 540.17	3	
04.66	4	
8 496.10	3	
50.04	4	
45.38	4	
8 381.93	3	
18.4	3	
8 262.09	4	
23.08	4	
7 970.44	3	
7 881.91	4	
7 784.11	5	



## INTERNATIONAL CRITICAL TABLES

U.—(Continued)			V (37, 62, 78, 90, 91, 146, 154, 159)			V.—(Continued)			V.—(Continued)		
$\lambda$	A	S	$\lambda$	A	S	$\lambda$	A	S	$\lambda$	A	S
7 631.72	3		8 919.8	3		4 462.367	9	9	3 727.46		10
19.34	3		8 255.8	4		I 60.31	10R	10R	15.47	6	10
7 533.91	5		53.5	4		52.03	8	10	I 03.566	8	3
7 425.49	3		41.6	4		I 44.22	8	8	00.34	1	8
7 128.88	4		03.0	4		I 41.686	7	8	3 695.867	8	3
01.61	3		I 8 161.03	4		I 37.841	8	6	I 92.22	8	4
7 074.78	4		I 16.76	5		I 21.586	8	5	I 90.29	8	4
6 826.90	4		7 338.90	4		16.61		10	I 88.070	8	3
6 465.00	4		6 753.03	4		I 08.516	6R	10R	69.42	1	8
49.19	10	1	I 6 531.43	10	6	I 08.209	6R	1	67.72	8	3
6 395.46	6		I 04.18	4	4	I 07.65	8R	4R	18.95	1	8
72.46	5		I 6 452.38	4		I 06.65	8R	5R	3 593.33	5	10
6 171.88	4		6 326.87	5	4	I 00.588	9	10	92.02	5	10
6 077.28	4		I 6 296.53	10	6	I 4 395.24	10	10	89.75	5	10
51.74	4	1	I 92.83	9	7	I 89.987	10R	10R	66.17	3	8
5 997.32	4		I 85.18	9	7	I 84.73	10R	10R	56.80	4	10
76.32	5		I 74.67	5	8	I 79.240	10R	10R	45.20	6	10
15.39	8	1	I 68.85	5	5	I 52.88	10	6	30.77	6	10
5 837.7	4	1	I 51.83	9	8	I 41.01	9	10	24.73	3	8
5 798.54	4	1	I 43.10	9	4	I 32.830	8	10	17.30	5	10
80.56	4		I 42.85	4	10	I 30.031	6	10	04.44	4	10
58.18	6		I 30.78	10	9	4 284.06	7	10	3 496.94	3	8
23.63	5	1	I 16.35	8	10	76.96	6	8	57.13	2	10
5 669.45	4		6 199.20	8	8	71.56	6	8	3 337.9		8
21.50	4	1	I 19.54	10R	8	68.64	8	8	3 279.84	3	10
10.88	5	1	I 11.67	10	9	I 09.85	6	8	76.12	10	10R
5 564.16	5	1	I 6 090.24	10R	10	05.08	2	10	71.11	10	10R
27.84	10	4	I 81.47	10	6	02.44	1	8	67.706	10	10R
5 492.94	8	4	I 39.74	10	10	4 183.4	2	10	54.75	2	8
81.20	5	3	I 5 737.07	7	7	I 34.47	9	10	37.87	6	10
75.71	5	3	31.28	8	5	I 32.00	10R	10	17.11	6	10
5 280.38	4	1	I 27.04	10R	10	I 28.074	10	10	I 02.38	5R	2
5 027.38	5	4	I 07.02	8R	9	I 16.70	10R	7	3 198.098	5R	2
4 899.27	4	2	I 03.61	10R	10	I 16.479	8	7	90.67	7	10R
19.48	4	2	I 5 698.53	10R	10	I 15.180	10	2	88.51	5	8R
4 772.70	4	3	70.87	9	8	I 05.166	10	4	87.70	5	8R
56.79	5	2	I 27.66	8	9	I 4 099.796	10	2	I 85.406	10R	2R
31.60	5	3	5 507.75	5	8	I 92.692	10	3	I 83.99	10R	2R
4 689.07	5	4	5 487.9	5	8	I 90.59	10	10	I 83.415	10R	2R
46.60	4	4	15.28	10	8	35.62	2	10	39.73	1	8
27.08	5	5	01.95	7	8	23.38	2	10	36.51	2	8
4 543.64	5	8	5 194.85	4	8	05.71	3	10	34.93	2	8
4 472.34	5	6	38.44	6	10	3 998.73	8	4	II 30.270	5	10R
4 393.60	5	2	28.54	8	9	97.13	3	8	II 26.21	6	4R
41.67	5	4	I 4 881.57	10R	10	90.57	10	6	II 25.288	8	2
4 287.87	4	3	I 75.48	10R	10	73.64	3	10	II 18.383	10R	10R
41.68	5	4	I 64.75	10R	9	51.96	3	10	II 10.71	8	10R
4 171.61	5	3	I 51.50	9	8	16.40	2	8	II 02.303	10	10R
63.70	5	2	I 07.56	10	8	14.31	2	8	II 3 093.14	4	10R
56.65	5	2	I 4 796.94	7	8	I 09.88	6R		66.37	4R	1R
4 090.13	6	4	I 86.52	6	8	02.258	8R	2	60.45	3R	
3 985.80	5	2	76.48	6	9	3 878.73	1	10	56.35	3R	2
32.04	5	3	I 4 619.68	8	9	I 75.081	8R	2	50.88	3R	3
3 859.57	5	3	I 4 594.10	10R	10	I 64.861	8	3	44.93	4R	1
31.45	4	3	I 86.367	8	9	I 55.852	9R	3	01.20	3	8R
3 670.07	4	3	I 80.402	8	9	47.32	4	10	2 989.59	1	3R
3 566.61	4	2	I 77.17	8	8	I 18.241	8	3	77.55	8	1
2 008		5	71.79	6	10	15.51	3	10	76.53	8	3
1 985		5	60.72	7	9	I 13.495	8	3	76.21	8	2
81		5	49.65	6	8	3 794.96	8	3	74.24	8	1
1 833		5	45.40	9	8	87.15	2	8	68.38	8	10R
1 587		5	4 488.90	8	10	70.97	3	10	II 57.52	8	6
764		5	69.71	8	8	45.80	3	10	55.80	8	
397		1				32.75	5	10	II 52.08	8	8R



V.—(Continued)			W.—(Continued)			W.—(Continued)			Xe.—II. Spectrum.—(Cont'd)	
$\lambda$	A	S	$\lambda$	A	S	$\lambda$	A	S	$\lambda$	G
II 2 944.6	2	8R	6 693.12	5		2 572.3		6	5 339.4	9
43.20	8	1	6 538.15	4		71.46	2	6	14.0	8
42.35	10R	2	6 445.15	4	2	2 488.8	2	6	5 292.2	10
II 41.43	3	10R	04.22	4	2	46.4	1	8	5 080.7	7
II 30.813	8	5R	6 292.05	4	2	2 397.11	2	10	4 921.5	6
II 24.650	8	8R	6 012.80	4	3	1 895.5		6	4 890.1	5
II 24.021	8	8R	5 947.58	4	2	1 788.3		5	83.5	6
23.626	8R		5 804.86	7	5	87.0		5	76.5	7
II 20.383	8	3	5 735.10	8	8	85.5		5	62.5	8
19.99	8	2	5 648.39	7	10	1 679.2		3	44.3	10
14.925	10	2	5 514.72	10	10	1 550.2		3	23.3	6
II 11.055	6	3R	5 492.34	10	10	Xe (7, 50, 175, 187)			4 698.0	5
10.385	8	4R	5 224.68	10	10	I: Spectrum			52.0	6
10.021	8	4R	5 071.74	5	10	$\lambda$		G	03.0	10
08.811	8R	8R	53.30	10	2	8 819.38		6	4 592.0	6
II 07.47	8	3R	15.34	8	8	8 409.17		4	85.5	10
06.13	8	4R	06.17	8	10	8 280.08		10	77.2	6
04.130	8	1	4 843.829	9	5	31.62		10	45.2	8
2 893.321	10	5R	4 680.52	8	5	7 642.04		4	40.9	8
92.67	10	5R	4 588.74	7	3	7 393.80		3	4 480.8	7
92.46	10		70.66	7	3	7 285.36		3	62.2	10
91.65	10	6R	4 484.20	8	4	6 882.07		3	48.1	10
84.79	6	10	4 302.12	8	5	6 727.90		3	34.2	6
82.51	6	8	4 294.62	6R	9	6 469.70		3	14.8	7
10.238	2	8	15.38	3	8	6 318.06		3	4 395.7	10
2 762.6		2R	4 074.37	7	6	6 182.44		2	93.2	10
15.69	10	5	08.76	10	10	4 923.246		5	30.5	10
06.19	8	3R	3 867.98	5	5	4 844.333		10	4 245.4	10
00.962	8	5R	3 736.24	1	10	29.705		4	38.2	10
2 687.99	10	5R	3 641.41	4	10	07.019		7	08.5	6
79.35	8	4	17.52	8R	2	4 734.154		8	4 193.1	8
78.600	7	3	13.79	3	10	4 697.020		6	80.0	10
77.830	7	4	3 592.42	3	10	71.225?		10	09.0	6
2 074.5		15	72.47	3	10	24.275?		9	4 057.4	5
1 454		2	45.23	6	3	03.028		10	50.0	6
37.3		2	08.74	6	5	4 582.746?		4	3 992.7	5
1 112		2	3 401.90	1	8	24.680?		6	50.6	8
723		3	3 376.14	1	10	00.978		8	22.5	10
684.5?		5	3 077.50	1	10	4 193.5		8	07.9	7
483.0		5	49.68	6R	1	16.1		7	3 895.0	6
			46.44	5R	1	09.7		5	80.5	6
			41.86	5R	1	4 078.8		10	77.8	8
			17.44	6R	2	3 967.6		4	41.5	7
			2 946.98	8R	3	51.0		10	3 781.0	10
			44.41	7R	3	3 650.2		4	76.3	7
			34.99	5R	3	II. Spectrum			3 676.6	7
			2 896.44	6R	3	$\lambda$		G	24.1	8
			96.01	4R	2	6 557		10	3 596.6	5
			79.40	5R	2	6 097.6		7	83.6	6
			79.11	5R	2	51.2		7	79.7	6
			18.07	5R	2	36.2		6	52.1	6
			2 774.48	5R	3	5 976.5		7	42.4	6
			74.01	5R	2	5 751.1		5	3 468.2	5
			70.90	4R	1	19.6		6	67.2	5
			69.76	4R	1	5 667.6		6	58.8	5
			68.99	4R	1	59.5		5	54.3	7
			64.28	4R	8	16.8		6	3 330.8	6
			62.34	4R	2	5 531.1		7	22.2	6
			02.1	1	10	5 472.7		7	3 285.8	8
			2 658.02	2	8	60.4		6	42.8	7
			2 589.14	2	8	39.0		8	39.3	6
			79.6		7	19.2		10	3 196.2	5
			79.3	1	5	5 372.4		8	51.0	6

W (10, 24, 75, 76, 90, 91, 116, 146)



INTERNATIONAL CRITICAL TABLES

Xe.—II. Spectrum.—(Cont'd)

λ	G
3 150.7	6
38.3	6
3 091.1	5
83.6	6
65.2	6
2 993.0	5
79.4	6
57.7	5
37.9	6
2 871.2	5
16.0	5
14.5	6
2 794.9	5
17.4	7
2 677.2	8
05.6	10
2 475.9	10

Yb* (65, 90, 91)		
λ	A	S
7 699.49	10	
7 527.58	5	
6 799.66	10	
6 667.85	10	
6 489.14	10	1
5 837.13	8	
5 720.02	10	
5 652.00	9	
5 556.47	10	1
39.05	10	
5 481.95	8	
5 352.94	5	1
35.14	6	1
5 277.07	6	
4 935.51	10	
4 786.60	10	10
81.90	8	
26.07	8	10
4 576.22	10	3
4 439.22	8	2
4 316.96	2	5
4 180.84	10	5
35.13	4	8
3 988.01	10	10
3 795.76	3	5
70.09	7	3
3 694.20	10	10
19.83	5	8
3 560.69	8	5
60.33	8	3
20.24	4	10
3 478.84	8	10
76.30	8	4
64.33	10	5
54.07	5	10
41.50	10	3
31.12	6	3
3 362.60	10	4
42.96	10	5
37.17	8	2
3 289.37	10	10
3 192.87	3	8

\* Ytterbium = Neoytterbium = Aldebaranium.

Yb.—(Continued)

λ	A	S
3 169.05	3	8
53.86	3	10
40.91	4	10
26.1		10
17.78	4	10
07.87	10	10R
3 065.03	4	10
31.12	10	5
29.6		10
17.57	3	10
09.39	3	8
05.76	5	10
2 994.80	3	8
70.56	6	5
19.36	4	10
14.23	2	10
2 859.81	3	6
51.17	4	10
2 750.49	5	10
2 672.64	3	4
42.53	1	8
2 464.53	10R	

Yt (58, 62, 66, 78, 90, 91, 130, 145, 290)

λ	A	S
II 7 881.7	2	
II 7 450.2	4	
7 346.8	4	
II 7 264.16	4	
7 191.65	3	
6 979.87	4	
II 51.67	4	
50.32	4	
6 887.22	4	
45.23	4	
II 6 795.41	4	1
I 93.71	4	1
35.99	4	
00.71	4	1
I 6 687.57	5	1
64.37	4	
II 13.75	5	3
6 538.58	4	2
I 6 435.03	8	8
I 6 222.58	6	2
I 6 191.72	7	4
I 38.45	4	2
I 6 023.42	4	2
09.20	5	3
5 945.72	4	1
II 5 781.68	4	2
II 28.90	4	2
06.73	4R	2
5 662.95	7R	10
48.46	4R	1
44.69	4R	1
30.13	6R	2
5 581.88	5R	2
77.42	4R	1
56.45	4R	1
II 44.60	5	2
27.55	6R	3

Yt.—(Continued)

λ	A	S
II 5 521.62	6R	3
II 09.91	9	4
03.45	8	2
II 5 497.41	5	8
66.46	10	3
II 02.78	5	8
II 5 205.71	10	10
II 00.41	10	10
II 5 123.21	6	4
II 5 087.42	10	10
II 4 900.12	10	10
II 4 883.69	10	10
59.83	6	3
II 54.88	10	10
52.69	6	4
45.68	6	5
39.86	9	10
II 23.31	4	10
II 4 682.31	5	10
I 74.84	8	5
58.31	6	3
I 43.69	8	5
4 527.79	7	3
27.26	8	5
05.96	8	3
II 4 422.60	10	10
II 4 398.03	8	10
II 74.95	10	10
II 58.72	7	10
48.79	9	3
II 09.62	10	10
02.30	10	3
4 251.18	7	2
II 35.71	8	5
20.62	7	1
II 4 177.52	10	10
I 74.14	7	4
I 67.52	8	4
I 42.87	8R	8
I 28.32	8R	8
I 02.38	9R	8
I 4 083.71	7	3
I 77.38	6R	5
I 47.65	7	4
II 3 982.61	10	10
II 50.35	10	10
II 3 788.69	9	10
II 74.33	10	10
II 47.55	6	10
II 10.30	10	10
3 668.48	3	10
I 20.94	10	8
II 11.05	10	10
II 01.92	10	10
II 00.73	10	10
I 3 592.91	8	4
84.51	4	10
48.99	10	10
3 496.09	9	10
3 361.99	5	10
II 27.88	10	10
II 3 242.28	10	10
II 16.67	10	10

Yt.—(Continued)

λ	A	S
II 3 203.32	7	10
II 00.26	7	10
II 3 195.61	8	10
73.05	4	10
29.93	3	8
II 3 095.88	6	2
2 946.0		10
2 817.0	1	10
2 422.20	4	8
14.7		10
2 367.2		10

Zn, (59, 60, 62, 74, 75, 78, 90, 91, 107, 111, 123, 139, 203, 204, 206, 207, 251, 254, 273, 276, 284, 287)

λ	A	S
16 504.0	4	
I 503.9	4	
I 485.7	4	
I 15 679.7	4	
I 14 038.5	10	
I 13 786.1	4	
I 781.4	2	
I 197.5	10	
I 150.4	10	
I 053.2	10	
I 11 054.2	10	
I 10 979	4	
I 970	4	
I 7 799.1	4	
II 32.63		10
II 7 588.61		15
II 7 478.73	4	20
7 338.9	4	
7 264.2	4	
7 026.1	4	
I 6 943.4	4	
I 38.5	6	
I 28.4	8	
II 6 482.98		15
I 79.0	7	
I 6 362.345	10	10
I 6 239.20	5	
I 37.9	6	
II 14.65		12
II 6 111.56		10
II 02.54	2	20
II 6 021.26	1	15
II 5 894.39	8	20
I 5 777.1	5	
I 75.6	6	
I 72.2	8	
I 5 310.90	4	
I 10.18	6	
I 08.57	8	
I 5 181.948	5	1
II 4 924.0	10	30
II 11.6	10	25
I 4 810.534	10R	10
I 4 722.162	10R	10
I 4 680.138	10R	10



## Zn.—(Continued)

$\lambda$	A	S
I 4 629.810	8	
4 057.87	6	1
II 3 840.84		15
II 06.39		10
I 3 345.9	8	2
I 45.6	8R	10
I 45.0	10R	10
I 02.9	8R	10
I 02.6	8R	10
I 3 282.30	8R	10
I 3 075.88	8R	6
I 72.10	10R	10
I 35.80	10R	6
I 18.38	6	3
I 2 802.0	3R	
I 00.8	7R	10
I 00.0	8R	
I 2 771.0	6R	
I 70.9	8R	8
I 56.47	6R	5
I 12.50	6	3
I 2 684.19	6	3
I 70.57	4	1
I 08.6	8R	3
I 2 582.5	8R	2
II 70.72		2R
I 69.92	6R	1
II 57.95	8	10
II 02.0	3	10
I 2 491.5	6	1
2 393.80	4	1
2 246.8	4	
I 2 138.5	3R	2R
II 00.0		5
II 2 061.9	4	4R
II 25.5	4	2R
1 864		5
39.3		6
34		7
11		7
1 767.8		7
50		7
46		8
43		10
07		7
1 673.2		7
51.9		7
45.0		8
39.5		9
29.4		9
22.9		7
20.0		6
I 01.2		6
I 1 589		10
I 1 457		8
677.9		5

Zr (5, 61, 77, 78, 90, 91, 157, 272)

$\lambda$	A	S
7 318.2	3	
7 280.3	4	
I 7 169.1	6	

## Zr.—(Continued)

$\lambda$	A	S
I 7 097.7	4	
6 990.82	5	
53.83	5	
6 846.95	4	
6 769.12	6	
6 489.64	6	1
70.21	6	1
6 313.01	7	1
6 299.63	7	1
I 6 143.19	7	1
I 27.44	7	1
5 879.77	8	1
I 5 680.88	6	1
20.13	6	1
5 528.39	5	1
02.13	6	1
5 385.12	7	1
11.39	5	1
5 191.58	4	
55.44	4	1
5 064.90	5	1
46.58	5	1
4 959.41	5	
09.57	6	
I 4 815.63	6	3
I 4 772.32	8	4
I 39.48	9	5
I 10.07	10	5
4 688.45	7	4
I 87.80	10	5
33.98	7	2
4 575.51	7	3
I 35.75	8	3
4 442.99	6	9
4 379.77	8	10
47.89	7	3
I 4 282.20	6	6
I 27.75	8	4
4 161.21	7	8
56.23	8	9
49.20	10	10
I 4 081.21	9	5
48.67	7	9
II 3 998.97	9	10
91.13	9	10
II 58.22	8	10
15.93	5	10
I 3 890.32	7	4
II 36.75	5	10
I 35.97	7	2
3 796.49	3	8
51.59	6	10
09.27	6	10
3 698.16	6	10
II 74.71	6	10
II 14.77	6	10
11.89	4	8
II 3 576.86	7	10
II 72.47	10	10
II 56.60	9	10
42.62	5	10
I 19.60	8	3
II 05.66	5	8
05.48	4	8

## Zr.—(Continued)

$\lambda$	A	S
II 3 496.21	10	10
81.15	8	10
79.39	7	9
63.01	4	10
II 38.23	10	10
II 30.53	7	9
II 3 391.98	10	10
II 57.26	8	4
56.09	8	4
3 284.71	8	4
II 79.27	8	4
II 73.05	8	9
I 3 182.87	7	5

## Zr.—(Continued)

$\lambda$	A	S
3 106.57	6	4
3 029.52	6	1
11.74	5	1
2 985.39	4	1
68.95	6	3
2 875.98	4	
44.58	4	4
2 752.21	4	3
34.84	5	5
2 678.64	5	5
2 571.41	6	8
68.87	5	6
2 449.84	4	3

## LITERATURE

(For a key to the periodicals see end of volume)

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- (<sup>10</sup>) Belke, *SI*, 17: 132, 145; 17. (<sup>11</sup>) Bertram, *SI*, 4: 16; 06. (<sup>12</sup>) Bloch, *SI*, 158: 784; 14. (<sup>13</sup>) Bloch and Bloch, *SI*, 158: 1416; 14. (<sup>14</sup>) Bloch and Bloch, *SI*, 171: 909; 20. (<sup>15</sup>) Bloch and Bloch, *SI*, 172: 803; 21. (<sup>16</sup>) Bloch and Bloch, *SI*, 172: 851; 21. (<sup>17</sup>) Bloch and Bloch, *SI*, 172: 962; 21. (<sup>18</sup>) Bloch and Bloch, *SI*, 177: 1025; 23.
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- (<sup>69</sup>) Eder, *SI*, 127 IIa: 1099; 18. (<sup>70</sup>) Eder, *SI*, 129 IIa: 421; 20. *SI*, 131 IIa: 199; 22. (<sup>71</sup>) Eder, *SI*, 228, 74: 45; 03. (<sup>72</sup>) Eder and Valenta, *SI*, 107 IIa: 41; 98. (<sup>73</sup>) Eder and Valenta, *SI*, 118 IIa: 511; 09. (<sup>74</sup>) Eder and Valenta, *SI*, 118 IIa: 1077; 09. (<sup>75</sup>) Eder and Valenta, *SI*, 119 IIa: 3; 10. (<sup>76</sup>) Eder and Valenta, *SI*, 119 IIa: 9; 10. (<sup>77</sup>) Eder and Valenta, *SI*, 119 IIa: 519; 10. (<sup>78</sup>) Eder and Valenta, *SI*, 228, 60: 241; 93.
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(187.1) Merton and Barrat, 62, 222: 369; 22. (188) Merton and Pilley, 5, 107: 411; 25. (189) Messerschmidt, 99, 5: 249; 07. (190) Millikan, *et. al.*, 21, 53: 150; 21. (191) Millikan, 197, 7: 289; 21. (192) Millikan and Bowen, 2, 23: 1; 24. (193) Millikan, Bowen and Sawyer, 21, 53: 150; 21. (194) Monk, 21, 62: 375; 25. (195) Morrow, 117, 13: 269; 12. (196) Morsch, 99, 3: 181; 05. (197) Müller, *Diss.*, Bonn, 1921. (198) Nacken, 99, 12: 54; 13. (199) Neovius, 526, 17: No. 8; 92. (200) Offermann, *Diss.*, Bonn, 1920. (201) Otsuka, 96, 26: 786; 26. (202) Paschen, 8, 27: 537; 08. (203) Paschen, 8, 29: 625; 09. (204) Paschen, 8, 30: 746; 09. (205) Paschen, 8, 33: 717; 10. (206) Paschen, 8, 35: 860; 11. (207) Paschen, 8, 40: 602; 13. (208) Paschen, 8, 50: 901; 16. (209) Paschen, 8, 60: 405; 19. 63: 201; 20. (210) Paschen, 8, 71: 142, 537; 23. (211) Paschen and Meissner, 8, 43: 1223; 14. (212) Pickhan, *Diss.*, Münster, 1920. (213) Piña de Rubies, 132, 15: 110; 17. (214) Piña de Rubies, 132, 15: 215; 17. (215) Piña de Rubies, 132, 15: 434; 17. (216) Piña de Rubies, 132, 16: 338; 18. (216.1) Piña de Rubies, 34, 181: 108; 25. (217) Porlessa, 36, 42 II: 42; 12. (218) Porlessa, 22, 20 I: 819; 11. 20 II: 176; 11. (219) Porlessa, 22, 20 II: 584, 642; 11. (220) Priest, 128, 2: 1; 12. (221) Puhlmann, 99, 17: 97; 17. (222) Quinke, 99, 14: 249; 15. (223) Randall, 21, 34: 1; 11. (224) Randall, 21, 43: 195; 15. (225) Randall and Barker, 21, 49: 42; 19. (226) Randall and Barker, 21, 49: 54; 19. (227) Ranken, *Diss.*, Helsingfors, 1897. (228) Richter, *Diss.*, Bonn, 1927. (228.1) Reinheimer, 8, 71: 162; 23. (229) Rowland and Harrison, 21, 7: 273; 98. (230) Rowland and Tatnall, 21, 1: 14; 95. (231) Rowland and Tatnall, 21, 1: 149; 95. (232) Rowland and Tatnall, 21, 2: 184; 95. (233) Rowland and Tatnall, 21, 3: 286; 96. (234) Royds, 3, 17: 202; 09. (235) Royds, 5, 83: 22; 09. (236) Ruark, 21, 58: 46; 23. (237) Runge, 21, 9: 281; 99. (238) Runge, 21, 10: 73; 99. (239) Rudgè and Paschen, 8, 61: 641; 97. (240) Runge and Paschen, 21, 8: 70; 98. (241) Runge and Paschen, 76, 1896: 639, 759. (242) Runge and Precht, 8, 14: 418; 04. (243) Rutherford and Royds, 3, 16: 313; 08. (244) Rütten and Morsch, 99, 3: 181; 05. (245) St. John and Babcock, 21, 53: 260; 21. (246) St. John and Ware, 21, 36: 14; 12. 39: 5; 14. (247) v. Salis, 8, 76: 145; 25. (248) Saltmarsh, 3, 47: 874; 24. (249) Saltmarsh, 5, 108: 332; 25. (250) Saunders, 21, 32: 153; 10. 40: 377; 14. 52: 265; 20. (251) Saunders, 21, 43: 234; 16. (252) Saunders, 21, 51: 23; 20. (253) Saunders, 21, 56: 73; 22. (254) Sawyer, 21, 52: 286; 20. (255) Scharbach, 99, 12: 145; 12. (256) Schillinger, 76, 118 IIa: 605; 09. (257) Schippers, 99, 11: 235; 13. (258) Schmitz, 99, 11: 209; 12. (259) Schulemann, 99, 10: 263; 12. (260) Schumacher, 99, 12: 149; 19. (261) Shaver, 69, 18 III: 23; 24. (262) Simeon, 5, 102: 484; 22. 104: 368; 23. (262.1) Simeon, 5, 104: 368; 23. (263) Smythe, 21, 54: 133; 21. (264) Sommer, 8, 75: 163; 24. (265) Stiles, 21, 30: 48; 09. (266) Symons, 99, 12: 277; 13. (267) Takamine and Nitta, 429, 2: 117; 17. (268) Turner, 2, 27: 397; 26. (269) Uhler and Browning, 12, 42: 389; 16. (270) Uhler and Patterson, 12, 36: 135; 13. (271) Uhler and Tanch, 21, 55: 291; 22. (272) Vahle, 99, 18: 84; 18. (273) Volk, *Diss.*, Tübingen, 1914. (274) Wagner, 99, 10: 69; 11. (275) Wallrath, *Diss.*, Bonn, 1923. (276) Walters, 31, No. 411; 21. (277) Watson, 5, 81: 181; 08. (278) Watson, 5, 82: 189; 09. (279) Watson, 5, 83: 50; 09. (280) Watteville, 99, 7: 279; 09. (281) Weigand, 99, 11: 261; 12. (282) Weinberg, 5, 107: 138; 25. (283) Wiedman, 8, 38: 1041; 12. (284) Wiedmann, *Diss.*, Tübingen, 1912. (285) Wirminghaus, 99, 20: 229; 21. (286) Wolff, 99, 3: 395; 05. (287) Wolff, 8, 42: 825; 13. (288) Wood and Fortrat, 21, 43: 73; 16. (289) Wood and Kimura, 21, 46: 181; 17. (290) Yntema and Hopkins, 48, 6: 121; 22. (291) Zumstein, 2, 28: 150; 26.

## PERSISTENT LINES AND RAIES ULTIMES OF THE CHEMICAL ELEMENTS

W. F. MEGGERS

The spectrochemical detection of the chemical elements is based on the identification of certain spectral lines which are characteristic of the atoms, and the most sensitive lines depend, in general, on the type of excitation. Sources in which the excitation is moderate (flames, ordinary arcs, uncondensed discharges in Geissler tubes) leave most of the atoms in a neutral condition, and the class *I* spectra predominate. More vigorous excitations (high potential condensed sparks, discharges in gas or vapor at low pressure, etc.) which ionize most of the atoms develop the class *II* spectra, while still more violent discharges bring out the *III* and higher classes of spectra corresponding to successive stages of ionization. Successive ionizations are increasingly difficult to produce, the spectra shift into the far ultraviolet and are for the most part still unknown; practical spectrochemical identifications are therefore limited almost entirely to arc and first spark spectra. The following lines have been established empirically or from the rules of spectral structure to be persistent in these spectra; the most sensitive line or *raie ultime* is printed in bold face. In many cases, *e.g.*, the halogens, the true *raies ultimes* lie in the Schumann region (vacuum spectroscopy), and the persistent lines

in the region readily observed by ordinary spectrographic methods (2000 to 9000 Å) are far less sensitive.

The true *raies ultimes* are the strongest lines in the spectra; they arise from the most probable electron transitions in the atom. In general, the excitation of these lines involves a transition of a single electron in such a way that the atomic energy is changed from the normal state to one in which the quantum numbers *l* and *j* are each increased by one unit. The combinations of spectral terms (energy states) giving rise to these lines appear in the last column; they show which spectra have been analyzed as to spectral structure and describe the normal states of the atoms (*l* = 0, 1, 2, 3, etc., for *S*, *P*, *D*, *F*, etc., terms; *j*, the inner quantum number, appears as a subscript to the term symbol; *v. p.* 392).

### PERSISTENT LINES AND RAIES ULTIMES

Arranged by Elements

The wave-lengths ( $\lambda$ ) tabulated below refer to air at 15°C and 1 atm., except those shorter than 1800 Å, which are vacuum values. Unit of  $\lambda$  = 1 Å =  $10^{-8}$  cm.



A I		Bi I.—(Continued)		Co II		Ge I		K I		N III	
$\lambda$	Terms	$\lambda$	Terms	$\lambda$	Terms	$\lambda$	Terms	$\lambda$	Terms	$\lambda$	Terms
1048.26	$p-s_2$	2809.63	$^2D_5-^2P_2$	2286.16	$^5F_5-^5G_6$	2651.15	$^3P_2-^3P_2$	4044.16	$^2S_1-^2P_2$	989.8	$^2P_1-^2D$
1060.70	$p-s_4$	2897.98	$^2D_7-^2P_1$	2307.84	$^5F_4-^5G_5$	2651.60	$^3P_1-^3P_1$	4047.22	$^2S_1-^2P_1$	991.6	$^2P_2-^2D$
6965.430	$s_5-p_2$	2938.31	$^2D_3$	2378.62	$^5F_5-^5D_4$	3039.08	$^1D_2-^1P_1$	7664.94	$^2S_1-^2P_2$	4097.3	$^2P_1-^2S_1$
7067.217	$s_5-p_3$	2989.04	$^2D_2$	2388.90	$^5F_5-^5F'_5$	3269.49	$^1D_2-^3P_1$	7699.01	$^2S_1-^2P_1$	4103.4	$^2P_2-^2S_1$
7503.868	$s_7-p_1$	3067.73	$^4S_7-^4P_1$	Cr I		4226.61	$^1S_0-^1P_1$	Kr I		Na I	
8115.308	$s_8-p_3$	Br I		4254.342	$^7S_3-^7P_4$	Gl; v. Be		5570.291		3302.34	$^2S_1-^2P_2$
Ag I		1540.8		4274.802	$^7S_3-^7P_3$	H I		5870.917		3302.94	$^2S_1-^2P_1$
3280.67	$^2S_1-^2P_2$	1633.8		4289.725	$^7S_3-^7P_2$	1215.7	$R\left(\frac{1}{1^2}-\frac{1}{2^2}\right)$	La I		5889.965	$^2S_1-^2P_2$
3382.89	$^2S_1-^2P_1$	Br II(?)		5204.54	$^5S_2-^5P_1$	6562.79	$R\left(\frac{1}{2^2}-\frac{1}{3^2}\right)$	5455.11	$^2D_3-^2D'_3$	5895.932	$^2S_1-^2P_1$
Ag II		4704.83		5206.039	$^5S_2-^5P_2$	4861.33	$R\left(\frac{1}{2^2}-\frac{1}{4^2}\right)$	5930.59	$^2D_3-^2F_4$	Nb; v. Cb	
2246.43	$^3D_5-^3F_4$	4785.48		5208.429	$^5S_2-^5P_3$	He I		6249.92	$^4F_5-^4G_6$	Nd I	
2437.77	$^3D_5-^3P_2$	4816.72		Cr II		584.4	$^1S_0-^1P_1$	La II		3951.15	
Al I		C I		2835.64	$^6D_5-^6F_6$	3888.64	$^3S_1-^3P_2$	3949.10	$^3D_5-^3F_4$	4177.34	
3082.162	$^2P_1-^2D_2$	2478.6	$^1S_0-^1P_1$	2843.25	$^6D_4-^6F_5$	5875.63	$^3P_2-^3D_3$	4077.35	$^3D_1-^3F_2$	4303.61	
3092.718	$^2P_2-^2D_3$	C II		2849.83	$^6D_3-^6F_4$	He II		4123.23	$^3D_2-^3F_3$	Ne I	
3092.85	$^2P_2-^2D_2$	1334.54	$^2P_1-^2D$	2855.66	$^6D_2-^6F_3$	303.8	$4R\left(\frac{1}{1^2}-\frac{1}{2^2}\right)$	Li I		735.95	$p-s_4$
3944.025	$^2P_1-^2S_1$	1335.72	$^2P_2-^2D$	2860.94	$^6D_1-^6F_2$	1640.5	$4R\left(\frac{1}{2^2}-\frac{1}{3^2}\right)$	3232.67	$^2S_1-^2P_{1,2}$	743.73	$p-s_2$
3961.537	$^2P_2-^2S_1$	4267.02	$^2D_2-^2F_3$	Cs I		4685.81	$4R\left(\frac{1}{3^2}-\frac{1}{4^2}\right)$	6707.86	$^2S_1-^2P_{1,2}$	5400.56	$s_4-p_1$
Al II		4267.27	$^2D_3-^2F_4$	8521.15	$^2S_1-^2P_2$	Hf I		Lu I		5832.488	$s_2-p_1$
1671.0	$^1S_0-^1P_1$	Ca I		8943.6	$^2S_1-^2P_1$	2898.25		4518.54		6402.246	$s_5-p_3$
1856.00	$^3P_0-^3S_1$	4226.728	$^1S_0-^1P_1$	4555.3	$^2S_1-^2P_2$	2904.42		Lu II		Ni I	
1858.13	$^3P_1-^3S_1$	4454.780	$^3P_0-^3D_1$	4593.2	$^2S_1-^2P_1$	2916.48		2894.86		3414.771	$^3D_5-^3F_4$
1862.48	$^3P_2-^3S_1$	4455.880	$^3P_1-^3D_2$	Cu I		2940.76		2911.40		3492.965	$^3D_2-^3P_1$
Al III		4456.62	$^3P_2-^3D_3$	3247.548	$^2S_1-^2P_2$	3072.88		3397.02		3515.057	$^3D_2-^3F_3$
1854.67	$^2S_1-^2P_2$	Ca II		3273.964	$^2S_1-^2P_1$	4093.17		3472.49		3524.543	$^3D_3-^3P_2$
1862.90	$^2S_1-^2P_1$	3933.670	$^2S_1-^2P_2$	Cu II		Hf II		3554.43		Ni II	
As I		3968.475	$^2S_1-^2P_1$	2135.98	$^3D_3-^3F_4$	2513.02		Mg I		2253.9	$^4F_7-^4G_3$
1889.9	$^4S_2-^4P_3$	Cb I		2192.27	$^3D_2-^3F_3$	2516.88		2852.130	$^1S_0-^1P_1$	2264.45	$^4F_3-^4G_4$
1936.9	$^4S_2-^4P_2$	4058.97	$^6D_5-^6F_6$	2247.80	$^3D_3-^3P_2$	2641.42		3829.36	$^3P_0-^3D_1$	2270.24	$^4F_4-^4G_5$
1972.0	$^4S_2-^4P_1$	4079.73	$^6D_4-^6F_5$	Dy I		2773.36		3832.31	$^3P_1-^3D_2$	2287.1	$^4F_5-^4G_6$
2288.14	$^2D_3-^2P_2$	4100.97	$^6D_3-^6F_4$	4000.50		2820.23		3838.29	$^3P_2-^3D_3$	O I	
2349.84	$^2D_2-^2P_1$	4123.85	$^6D_2-^6F_3$	4046.00		3134.72		Mg II		1302.27	$^3P_2-^3S_1$
2780.23	$^2P'_2-^2P_2$	4137.13	$^6D_1-^6F_2$	4077.98		Hg I		2795.540	$^2S_1-^2P_2$	1304.96	$^3P_1-^3S_1$
2800.46	$^2P'_1-^2P_1$	Cb II		4167.99		1849.6	$^1S_0-^1P_1$	2802.712	$^2S_1-^2P_1$	1306.12	$^3P_0-^3S_1$
Au I		3094.19	$^5F_5-^5G_6$	4211.74		2536.52	$^1S_0-^3P_1$	Mn I		7771.97	$^5S_2-^5P_3$
2427.96	$^2S_1-^2P_2$	3130.78	$^5F_4-^5G_5$	Er I		3650.15	$^3P_2-^3D_3$	4030.760	$^6S_3-^6P_4$	7774.01	$^5S_2-^5P_2$
2675.95	$^2S_1-^2P_1$	3163.37	$^5F_3-^5G_4$	3499.12		3654.83	$^3P_1-^3D_2$	4033.074	$^6S_3-^6P_3$	7775.68	$^5S_2-^5P_1$
B I		3194.95	$^5F_2-^5G_3$	3692.65		3662.88	$^3P_0-^3D_1$	4034.489	$^6S_3-^6P_2$	Os I	
2496.778	$^2P_1-^2S_1$	3225.47	$^5F_1-^5G_2$	3906.34		Hg II		Mn II		3262.30	
2497.733	$^2P_2-^2S_1$	Cd I		Eu I		1649.8	$^2S_1-^2P_2$	2576.12	$^7S_3-^7P_4$	3267.94	
B II		2288.03	$^1S_0-^1P_1$	4129.72		1942.3	$^2S_1-^2P_1$	2593.733	$^7S_3-^7P_3$	3301.56	
1362.46	$^1S_0-^1P_1$	3403.653	$^3P_0-^3D_1$	4205.03		Ho I		2605.69	$^7S_3-^7P_2$	3752.54	
3452.33		3466.201	$^3P_1-^3D_2$	F I		3748.19		Mo I		3782.20	
Ba I		3610.510	$^3P_2-^3D_3$	6856.01	$^4P_3-^4D_4$	3891.02		3798.26	$^5S_2-^5P_3$	P I	
5424.63	$^3P_2-^3D_3$	Cd II		6902.46	$^4P_2-^4D_3$	Ho II		3864.12	$^5S_2-^5P_2$	1774.8	$^4S_2-^4P_3$
5519.11	$^3P_1-^3D_2$	2144.39	$^2S_1-^2P_2$	Fe I		2936.8		3902.96	$^5S_2-^5P_1$	1782.7	$^4S_2-^4P_2$
5535.53	$^1S_0-^1P_1$	2265.03	$^2S_1-^2P_1$	3719.938	$^5D_4-^5F_5$	I I		Mo II		1787.5	$^4S_2-^4P_1$
5777.7	$^3P_0-^3D_1$	Ce II		3737.135	$^5D_3-^5F_4$	1782.9		2816.15	$^6D_5-^6F_6$	2136.8	$^2D_3-^2P_2$
Ba II		4012.40		3745.564	$^5D_2-^5F_3$	2062.1		2848.21	$^6D_4-^6F_5$	2149.8	$^2D_2-^2P_1$
4554.037	$^2S_1-^2P_2$	4040.76		3748.264	$^5D_1-^5F_2$	5161.2		2871.50	$^6D_3-^6F_4$	2536.38	$^2P'_2-^2P_2$
4934.09	$^2S_1-^2P_1$	4165.61		3745.902	$^5D_0-^5F_1$	5464.6		2891.00	$^6D_2-^6F_3$	2554.02	$^2P'_1-^2P_1$
Be I		4186.60		Fe II		In I		2909.11	$^6D_1-^6F_2$	Pb I	
2348.62	$^1S_0-^1P_1$	Cl I		2382.04	$^6D_5-^6F_6$	4101.76	$^2P_1-^2S_1$	N I		2170.0	$^3P_0-^3D_1$
3321.01	$^3P_0-^3S_1$	1379.6		2395.63	$^6D_4-^6F_5$	4511.31	$^2P_2-^2S_1$	1199.5	$^4S_2-^4P_3$	2833.07	$^3P'_0-^3P'_1$
3321.09	$^3P_1-^3S_1$	1396.5		2404.886	$^6D_3-^6F_4$	Ir I		1200.2	$^4S_2-^4P_2$	3639.584	$^3P_1-^3P'_1$
3321.35	$^3P_2-^3S_1$	4794.5		2410.53	$^6D_2-^6F_3$	2849.74		1200.7	$^4S_2-^4P_1$	3683.472	$^3P_1-^3P'_0$
Be II		4810.0		2413.312	$^6D_1-^6F_2$	2924.81		4099.96	$^3P_1-^3D_2$	4057.830	$^3P_2-^3P'_1$
3130.42	$^2S_1-^2P_2$	4819.4		Ga I		3220.79		4109.94	$^3P_2-^3D_3$	Pb II	
3131.06	$^2S_1-^2P_1$	Co I		4033.01	$^2P_1-^2S_1$	3437.05		N II		1682.4	$^2P_1-^2S_1$
Bi I		3453.514	$^4F_5-^4G_6$	4172.05	$^2P_2-^2S_1$	3513.67		5666.6	$^3P_1-^3D_2$	2203.57	$^2P_2-^2S$
2061.71	$^4S_2-^4P_3$	3465.794	$^4F_5-^4G_5$	Gd I				5675.9	$^3P_0-^3D_1$		
2276.57	$^4S_2-^4P_2$	3529.814	$^4F_4-^4G_5$	3646.19				5679.5	$^3P_2-^3D_3$		
2780.52	$^2D_2$			3768.40							



Pd I		Sb I		Th I		Yb I		Zn II		Zr I.—(Continued)	
$\lambda$	Terms	$\lambda$	Terms	$\lambda$	Terms	$\lambda$	Terms	$\lambda$	Terms	$\lambda$	Terms
3404.59	$^3D_3-^3F_4$	2068.38	$^4S_2-^4P_3$	3538.75		3289.37		2025.5	$^2S_1-^2P_2$	4739.477	$^4F_7-^4G_4$
3421.23	$^3D_2-^3D'_2$	2175.88	$^4S_2-^4P_2$	3601.05		3694.20		2061.9	$^2S_1-^2P_1$	4772.313	$^4F_7-^4G_4$
3516.95	$^3D_2-^3P_1$	2311.50	$^4S_2-^4P_1$	4019.14		3988.01				4815.62	$^4F_7-^4G_4$
3609.55	$^3D_2-^3F_3$	2528.53	$^2D_3-^2P_2$		Th II						
3634.68	$^3D_3-^3P_2$	2598.08	$^2D_2-^2P_1$	3290.59							
	Pd II	3232.52	$^2P'_2-^2P_2$		Ti I						
2488.92		3267.48	$^2P'_1-^2P_1$	3635.467	$^3F_2-^3G_3$	2138.5	$^1S_0-^1P_1$	3519.605	$^3F_4-^3G_5$		
2498.79			Sc I	3642.680	$^3F_3-^3G_4$	3282.32	$^3P_0-^3D_1$	3547.691	$^3F_2-^3G_4$	3391.976	$^4F_7-^4G_4$
2505.72		3907.49	$^2D_2-^2F_3$	3653.497	$^3F_4-^3G_5$	3302.6	$^3P_1-^3D_2$	3601.19	$^3F_2-^3G_3$	3438.23	$^4F_7-^4G_4$
2658.74		3911.81	$^2D_3-^2F_4$	4981.73	$^5F_5-^5G_6$	3344.5	$^3P_2-^3D_3$	4687.803	$^5F_5-^5G_6$	3496.208	$^4F_7-^4G_4$
2854.60			Sc II	4991.07	$^5F_4-^5G_5$			4710.075	$^5F_4-^5G_5$	3572.472	$^4F_7-^4G_4$
	Pr I	3613.83	$^3D_3-^3F_4$	4999.511	$^5F_3-^5G_4$						
4062.83		3630.75	$^3D_2-^3F_3$	5007.214	$^5F_2-^5G_3$						
4179.43		3642.81	$^3D_1-^3F_2$	5014.25	$^5F_1-^5G_2$						
4189.52			Se I		Ti II						
4225.34		1960.2	$^3P_2-^3S_1$	3349.039	$^4F_5-^4G_6$	303.8	He II	2061.9	Zn II	2528.516	Si I
	Pt I	2039.7	$^3P_1-^3S_1$	3361.215	$^4F_4-^4G_5$	584.4	He I	62.1	I I	28.53	Sb I
2659.44	$^3D_3-7_4$	2062.6	$^3P_0-^3S_1$	3372.80	$^4F_3-^4G_4$	735.95	Ne I	62.6	Se I	30.73	Te I
2830.29	$^3D_3-4_3$	4730.9	$^5S_2-^5P_3$	3383.765	$^4F_2-^4G_3$	743.73	Ne I	68.38	Sb I	36.38	P I
2929.79	$^3D_3-3_3$	4739.1	$^5S_2-^5P_2$		Tl I	989.8	N III	2135.98	Cu II	36.52	Hg I
2997.96	$^1D_2-3_3$	4742.3	$^5S_2-^5P_1$		Tu I	991.6	N III	36.8	P I	54.02	P I
3064.71	$^3D_3-1_2$		Si I	3775.73	$^3P_1-^3S_1$	1048.26	A I	38.5	Zn I	76.12	Mn II
	Ra I	2506.904	$^3P_1-^3P'_2$	5350.47	$^3P_2-^3S_1$	1066.70	A I	42.75	Te I	89.2	W II
4825.94	$^1S_0-^1P_1$	2516.119	$^3P_2-^3P'_2$		U I	1199.5	N I	44.39	Cd II	93.733	Mn II
	Ra II	2528.516	$^3P_2-^3P'_1$	3462.21		1200.2	N I	49.8	P I	98.08	Sb I
3814.44	$^2S_1-^2P_2$	2881.587	$^1D_2-^1P_1$	3761.34		00.7	N I	70.0	Pb I	2605.69	Mn II
4682.20	$^2S_1-^2P_1$	3905.52	$^1S_0-^1P_1$	3761.91		15.7	H I	75.88	Sb I	41.42	Hf II
	Rb I		Si II		V I	95.8	Xe I	92.27	Cu II	51.15	Ge I
4201.81	$^2S_1-^2P_2$	1526.83	$^3P_1-^3S_1$	3552.20		1302.27	O I	2203.57	Pb II	51.60	Ge I
4215.58	$^2S_1-^2P_1$	1533.55	$^3P_2-^3S_1$	3672.59		04.96	O I	46.43	Ag II	58.74	Pd II
7800.30	$^2S_1-^2P_2$		Sn I	4241.68		06.12	O I	47.80	Cu II	59.44	Pt I
7947.63	$^2S_1-^2P_1$	2839.987	$^3P_2-^3P'_2$		V II	34.54	C II	53.9	Ni II	75.95	Au I
	Rh I	2863.322	$^3P_0-^3P'_1$	3183.415	$^4F_3-^4G_4$	35.72	C II	64.45	Ni II	78.73	Ru II
3323.10	$^4F_4-^4G_5$	3009.135	$^3P_1-^3P'_1$	3183.96	$^4F_4-^4G_5$	62.46	B II	65.03	Cd II	92.10	Ru II
3396.82	$^4F_5-^4F'_5$	3034.116	$^3P_1-^3P'_0$	3184.00	$^4F_2-^4G_3$	79.6	Cl I	70.24	Ni II	2712.40	Ru II
3434.90	$^4F_5-^4G_6$	3175.047	$^3P_2-^3P'_1$	3185.406	$^4F_5-^4G_6$	96.5	Cl I	76.57	Bi I	69.65	Te I
3657.99	$^4F_4-^4D_3$	3262.33	$^1D_2-^1P_1$		V II	1469.9	Xe I	86.16	Co II	73.36	Hf II
3692.35	$^4F_5-^4D_4$	4524.74	$^1S_0-^1P_1$	3093.13	$^5F_5-^5G_6$	1526.83	Si II	87.1	Ni II	80.23	As I
	Ru I		Sr I	3102.30	$^5F_4-^5G_5$	33.55	Si II	88.03	Cd I	80.52	Bi I
3436.74	$^5F_4-^5G_5$	4607.342	$^1S_0-^1P_1$	3110.71	$^5F_3-^5G_4$	40.8	Br I	88.14	As I	95.540	Mg II
3498.95	$^5F_5-^5G_6$	4832.07	$^3P_2-^3D_3$	3118.38	$^5F_2-^5G_3$	1633.8	Br I	2307.84	Co II	2802.712	Mg II
3596.17	$^5F_5-^5G_4$	4872.48	$^3P_1-^3D_2$	3125.29	$^5F_1-^5G_2$	40.5	He II	11.50	Sb I	09.63	Bi I
	Ru II	4962.25	$^3P_0-^3D_1$		W I	49.8	Hg II	48.62	Be I	16.15	Mo II
2678.73			Sr II	4008.76	$^7S_3-^7P_4$	71.0	Al II	49.84	As I	20.23	Hf II
2692.10		4077.714	$^3S_1-^3P_2$	4294.62	$^7S_3-X_2$	82.4	Pb II	78.62	Co II	30.29	Pt I
2712.40		4215.515	$^3S_1-^3P_1$	4302.12	$^7S_3-^5P_3$	1774.8	P I	82.04	Fe II	33.07	Pb I
2945.67			Ta I		W II	82.7	P I	83.27	Te I	35.64	Cr II
2965.55		3311.14		2397.11		82.9	I I	85.78	Te I	39.987	Sn I
2976.58		3318.85		2589.2		87.5	P I	88.90	Co II	43.25	Cr II
	S I	3406.65		3613.79		1807.4	S I	95.63	Fe II	48.21	Mo II
1807.4	$^3P_2-^3S_1$		Tb I		Xe I	20.5	S I	97.11	W II	49.74	Ir II
1820.5	$^3P_1-^3S_1$					26.4	S I	2404.886	Fe II	49.83	Cr II
1826.4	$^3P_0-^3S_1$	3509.18		1295.8	$p-s_2$	49.6	Hg I	10.53	Fe II	52.130	Mg I
4694.2	$^5S_2-^5P_3$	3561.75		1469.9	$p-s_4$	54.67	Al III	13.312	Fe II	54.60	Pd II
4695.5	$^5S_2-^5P_2$	3848.76		4500.978		56.00	Al II	27.96	Au I	55.66	Cr II
4696.3	$^5S_2-^5P_1$	3874.19		4624.275		58.13	Al II	37.77	Ag II	60.46	As I
9212.8	$^5S_2-^5P_3$		Te I	4671.225		62.48	Al II	78.6	C I	60.94	Cr II
9228.2	$^5S_2-^5P_2$	2142.75	$^3P_2-^3S_1$		Yt I	62.90	Al III	88.92	Pd II	63.322	Sn I
9237.7	$^5S_2-^5P_1$	2383.27	$^3P_0-^3S_1$	4643.69	$^3D_2-^2F_3$	89.9	As I	96.778	B I	71.50	Mo II
	Sa I	2385.78	$^3P_1-^3S_1$	4674.84	$^3D_3-^2F_4$	1936.9	As I	97.733	B I	81.587	Si I
4390.87		2530.73	$^3P_1-^5S_2$		Yt II	42.3	Hg II	98.79	Pd II	91.00	Mo II
4424.35		2769.65	$^1D_2-^3S_1$	3710.30	$^3D_3-^3F_4$	60.2	Se I	2505.72	Pd II	94.86	Lu II
4434.34				3774.33	$^3D_2-^3F_3$	72.0	As I	06.904	Si I	97.98	Bi I
				3788.69	$^3D_1-^3F_2$	2025.5	Zn II	13.02	Hf II	98.25	Hf I
						39.7	Ge I	16.119	Si I	2904.42	Hf I
						61.71	Bi I	16.88	Hf II	09.11	Mo II

## PERSISTENT LINES AND RAIES ULTIMES

Arranged by wave-lengths  
Unit of  $\lambda = 1 \text{ \AA} = 10^{-8} \text{ cm.}$



## PERSISTENT LINES AND RAIES ULTIMES.—Arranged by wave lengths.—(Continued)

2911.40 Lu II	3290.59 Th II	3596.17 Ru I	3907.49 Sc I	4226.61 Ge I	4934.09 Ba II
16.48 Hf I	3301.56 Os I	3601.05 Th I	11.81 Sc I	26.728 Ca I	62.25 Sr I
24.81 Ir I	02.34 Na I	01.19 Zr I	33.670 Ca II	41.68 U I	81.73 Ti I
29.79 Pt I	02.6 Zn I	09.55 Pd I	44.025 Al I	54.342 Cr I	91.07 Ti I
36.8 Ho II	02.94 Na I	10.510 Cd I	49.10 La II	67.02 C II	99.511 Ti I
38.31 Bi I	11.14 Ta I	13.79 W II	51.15 Nd I	67.27 C II	5007.214 Ti I
40.76 Hf I	18.85 Ta I	13.83 Sc II	61.537 Al I	74.802 Cr I	14.25 Ti I
45.67 Ru II	21.01 Be I	30.75 Sc II	68.475 Ca II	89.725 Cr I	5161.2 I I
65.55 Ru II	21.09 Be I	34.68 Pd I	88.01 Yb I	94.62 W I	5204.54 Cr I
76.58 Ru II	21.35 Be I	35.467 Ti I	4000.50 Dy I	4302.12 W I	06.039 Cr I
89.04 Bi I	23.10 Rh I	39.584 Pb I	08.76 W I	03.61 Nd I	08.429 Cr I
97.96 Pt I	44.5 Zn I	42.680 Ti I	12.40 Ce II	90.87 Sa I	5350.47 Tl I
3009.135 Sn I	49.039 Ti II	42.81 Sc II	19.14 Th I	4424.35 Sa I	5400.56 Ne I
34.116 Sn I	61.215 Ti II	46.19 Gd I	30.760 Mn I	34.34 Sa I	24.63 Ba I
39.08 Ge I	72.80 Ti II	50.15 Hg I	33.01 Ga I	54.780 Ca I	55.11 La I
64.71 Pt I	82.89 Ag I	53.497 Ti I	33.074 Mn I	55.880 Ca I	64.6 I I
67.73 Bi I	83.765 Ti II	54.83 Hg I	34.489 Mn I	56.62 Ca I	5519.11 Ba I
72.88 Hf I	91.976 Zr II	57.99 Rh I	40.76 Ce II	4500.978 Xe I	35.53 Ba I
82.162 Al I	96.82 Rh I	62.88 Hg I	44.16 K I	11.31 In I	70.291 Kr I
92.718 Al I	97.02 Lu II	72.59 U I	46.00 Dy I	18.54 Lu I	5666.6 N II
92.85 Al I	3403.653 Cd I	83.472 Pb I	47.22 K I	24.74 Sn I	75.9 N II
93.13 V II	04.59 Pd I	92.35 Rh I	57.830 Pb I	54.037 Ba II	79.5 N II
94.19 Cb II	06.65 Ta I	92.65 Er I	58.97 Cb I	55.3 Cs I	5777.7 Ba I
3102.30 V II	14.771 Ni I	94.20 Yb I	62.83 Pr I	93.2 Cs I	5832.488 Ne I
10.71 V II	21.23 Pd I	3710.30 Yt II	77.35 La II	4607.342 Sr I	70.917 Kr I
18.38 V II	34.90 Rh I	19.938 Fe I	77.714 Sr II	24.275 Xe I	75.63 He I
25.29 V II	36.74 Ru I	37.135 Fe I	77.98 Dy I	43.69 Yt I	89.965 Na I
30.42 Be II	37.05 Ir I	45.564 Fe I	79.73 Cb I	71.225 Xe I	95.932 Na I
30.78 Cb II	38.23 Zr II	45.902 Fe I	93.17 Hf I	74.84 Yt I	5930.59 La I
31.06 Be II	52.33 B II	48.19 Ho I	97.3 N III	82.20 Ra II	6249.92 La I
34.72 Hf II	53.514 Co I	48.264 Fe I	99.96 N I	85.81 He II	6402.246 Ne I
63.37 Cb II	62.21 Tu I	52.54 Os I	4100.97 Cb I	87.803 Zr I	6562.79 H I
75.047 Sn I	65.794 Co I	61.34 Tu I	01.76 In I	94.2 S I	6707.86 Li I
83.415 V I	66.201 Cd I	61.91 Tu I	03.4 N III	95.5 S I	6856.01 F I
83.96 V I	72.49 Lu II	68.40 Gd I	09.94 N I	96.3 S I	6902.46 F I
84.00 V I	92.965 Ni I	74.33 Yt II	23.23 La II	4704.83 Br II	65.430 A I
85.408 V I	96.208 Zr II	75.73 Tl I	23.85 Cb I	10.075 Zr I	7067.217 A I
94.95 Cb II	98.95 Ru I	82.20 Os I	29.72 Eu II	30.9 Se I	7503.868 A I
3220.79 Ir I	99.12 Er I	88.69 Yt II	37.13 Cb I	39.1 Se I	7664.94 K I
25.47 Cb II	3509.18 Tb I	98.26 Mo I	65.61 Ce II	39.477 Zr I	99.01 K I
32.52 Sb I	13.67 Ir I	3814.44 Ra II	67.99 Dy I	42.3 Se I	7771.97 O I
32.67 Li I	15.057 Ni I	29.36 Mg I	72.05 Ga I	72.313 Zr I	74.01 O I
47.548 Cu I	16.95 Pd I	32.31 Mg I	77.34 Nd I	85.48 Br II	75.68 O I
62.30 Os I	19.605 Zr I	38.29 Mg I	79.43 Pr I	94.5 Cl I	7800.30 Rb I
62.33 Sn I	24.543 Ni I	48.76 Tb I	86.60 Ce II	4810.0 Cl I	7947.63 Rb I
67.48 Sb I	29.814 Co I	64.12 Mo I	89.52 Pr I	15.62 Zr I	8115.308 A I
67.94 Os I	38.75 Th I	74.19 Tb I	4201.81 Rb I	16.72 Br II	8521.15 Cs I
69.49 Ge I	47.691 Zr I	88.64 He I	05.03 Eu I	19.4 Cl I	8943.6 Cs I
73.964 Cu I	52.20 U I	91.02 Ho I	11.74 Dy I	25.94 Ra I	9212.8 S I
80.67 Ag I	54.43 Lu II	3902.96 Mo I	15.515 Sr II	32.07 Sr I	28.2 S I
82.32 Zn I	61.75 Tb I	05.52 Si I	15.58 Rb I	61.33 H I	37.7 S I
89.37 Yb I	72.472 Zr II	06.34 Er I	25.34 Pr I	72.48 Sr I	



## BIBLIOGRAPHY OF ABSORPTION SPECTRA OF SOLUTIONS

EMMA P. CARR AND MARY L. SHERRILL

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Bibliography and index: Infra-red. Ultra-violet and visible.	Bibliographie et index. Infra-rouge. Ultra-violet et visible.	Literatur und Index. Infrarotes Gebiet. Ultraviolette und sichtbares Gebiet.	Bibliografia e indice. Infrarosso..... Ultravioletto e visibile	327
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ABBREVIATIONS, SIGNS, SYMBOLS AND FORMS	ABRÉVIATIONS, SIGNES, SYMBOLES ET FORMES	ABKÜRZUNGEN, ZEICHEN, SYMBOLE UND FORMEN	ABBREVIAZIONI, SEGNI, SIMBOLI E FORMULE	
All literature referred to contains an absorption curve of the substance in question unless otherwise indicated.	Toutes les sources bibliographiques mentionnées, contiennent une courbe d'absorption de la substance en question, à moins d'une autre indication.	Sämtlich hier angegebene Literatur enthält eine Absorptionskurve der in Frage stehenden Substanz, ausser es ist etwas anderes angegeben.	Tutte le pubblicazioni alle quali ci si riferisce contengono una curva di assorbimento della sostanza in questione a meno che non venga altrimenti indicato.	
† The article contains some description of the absorption but no curve.	† L'article contient une description de l'absorption mais aucune courbe.	† Der Abschnitt enthält einige Angaben über die Absorption aber keine Kurve.	† L'articolo contiene qualche indicazione sopra l'assorbimento ma non contiene curve.	
‡ The article contains either numerical data or a curve based on quantitative measurement of the extinction coefficients.	‡ L'article contient ou des données numériques ou une courbe basée sur la mesure quantitative des coefficients d'extinction.	‡ Der Abschnitt enthält entweder numerische Daten oder eine Kurve, die sich auf Grund quantitativer Messungen des Extinktionskoeffizienten ergeben.	‡ L'articolo contiene valori numerici oppure una curva basata su misure quantitative dei coefficienti di estinzione.	
EtOH, Et <sub>2</sub> O, alk., etc. Abbreviations for solvents in which the determinations were made.	EtOH, Et <sub>2</sub> O, alk., etc. Abréviations pour les solvants dans lesquels les déterminations ont été faites.	EtOH, Et <sub>2</sub> O, alk., etc. Abkürzungen für die Lösungsmittel in welchen die Messungen ausgeführt worden sind.	EtOH, Et <sub>2</sub> O, alk., etc. Abbreviazione per solventi nei quali furono fatte le determinazioni.	
EtOH + HCl The solvent is a mixture of the two ingredients indicated.	EtOH + HCl Le solvant est un mélange des deux substances indiquées.	EtOH + HCl Das Lösungsmittel ist eine Mischung der zwei angegebenen Komponenten.	EtOH + HCl Il solvente è una miscela delle due sostanze indicate.	
EtOH, (+HCl), (+alk.), etc. The solvents are ethyl alcohol, EtOH + HCl, and EtOH + alkalies (as NaOH, KOH, etc.).	EtOH, (+HCl), (+alk.), etc. Les solvants sont l'alcool éthylique, EtOH + HCl, et EtOH + alcalis (comme NaOH, KOH, etc.).	EtOH, (+HCl), (+alk.), etc. Die Lösungsmitteln sind Äthylalkohol, EtOH + HCl und EtOH + Alkalien (wie NaOH, KOH, u. s. w.).	EtOH, (+HCl), (+alk.), etc. I solventi sono alcool etilico, EtOH + HCl, e EtOH + alcali (come NaOH, KOH, etc.).	
P The absorption measurements are made of the pure substance in the liquid state.	P Les mesures d'absorption ont été faites pour la substance pure à l'état liquide.	P Die Absorptionsmessungen sind an reinen Stoffen in flüssigem Zustande gemacht worden.	P Le misure degli assorbimenti si riferiscono alla sostanza pura allo stato liquido.	
Vap. The absorption measurements are made in the vapor state.	Vap. Les mesures d'absorption ont été faites pour la substance à l'état de vapeur.	Vap. Die Absorptionsmessungen sind an Stoffen im gasförmigen Zustande ausgeführt worden.	Vap. Le misure dell'assorbimento si riferiscono allo stato di vapore.	



# ABSORPTION SPECTRA OF SOLUTIONS OF INORGANIC COMPOUNDS EXCEPT THE SALT-DERIVATIVES OF ORGANIC COMPOUNDS

*Scope.*—Complete literature references are given for absorption measurements of solutions of inorganic substances in the infra-red region. For the visible and ultra-violet region an index is given below to the numerical data, and literature references for work published since 1910 except that of H. C. Jones and his collaborators who have examined the absorption spectra of several hundred inorganic substances in solution. The results of their work have been collected elsewhere (341.5, 343, 343.5, 344, 345) and are supplementary to this report.

TABLE A-B.—STANDARD ARRANGEMENT  
(v. Vol. III, p. viii)

The solvent is water unless otherwise stated

Formula	Solvents and literature
<b>Infra-red</b>	
HCl	(1, † 91)
I	CCl <sub>4</sub> (169 †); EtOH, CS <sub>2</sub> (99)
H <sub>2</sub> SO <sub>4</sub>	(1, † 103, 489)
NH <sub>3</sub>	(1, † 169, † 200)
HNO <sub>3</sub>	(1, † 489)
NH <sub>4</sub> NO <sub>3</sub>	(107, 207, † 343, † 489)
NH <sub>4</sub> Cl	(207, † 343 †)
NH <sub>4</sub> Br	(344)
(NH <sub>4</sub> ) <sub>2</sub> SO <sub>4</sub>	(169 †)
SiHCl <sub>3</sub>	(347 †)
ZnSO <sub>4</sub>	(107, 344, 582)
Zn(NO <sub>3</sub> ) <sub>2</sub>	(107, 344, 582)
CuCl <sub>2</sub>	(50, † 107, 166, † 326 †)
CuBr <sub>2</sub>	(326 †)
CuSO <sub>4</sub>	(50, † 53, † 78, † 166, † 452, † 489 †); cf. Fig. 5
CuSO <sub>4</sub> ·4NH <sub>3</sub> ·H <sub>2</sub> O	(50 †)
Cu(C <sub>2</sub> H <sub>3</sub> O <sub>2</sub> ) <sub>2</sub>	(50 †)
AgNO <sub>3</sub>	(107)
CoF <sub>2</sub>	(326 †)
CoCl <sub>2</sub>	(106, 326 †); MeOH, EtOH, PrOH (345 †)
CoBr <sub>2</sub>	(326 †)
CoI <sub>2</sub>	(326 †)
CoSO <sub>4</sub>	(326, † 345, † 489 †)
Co(NO <sub>3</sub> ) <sub>3</sub>	(326, † 345, † 489 †)
Co salts	(78 †)
NiCl <sub>2</sub>	(326 †); MeOH, EtOH, PrOH (345 †)
NiBr <sub>2</sub>	(326 †)
NiSO <sub>4</sub>	(106, 345, † 489 †)
Ni(NO <sub>3</sub> ) <sub>2</sub>	(50, † 106, 345 †)
NiCl <sub>2</sub> ·6NH <sub>3</sub>	(345 †)
Ni(C <sub>2</sub> H <sub>3</sub> O <sub>2</sub> ) <sub>2</sub>	(106 †)
Ni salts	(78 †)
CrCl <sub>3</sub>	(345 †)
Cr <sub>2</sub> (SO <sub>4</sub> ) <sub>3</sub>	(106, 345 †)
Cr(NO <sub>3</sub> ) <sub>3</sub>	(345 †)
UCl <sub>4</sub>	(50 †)
AlCl <sub>3</sub>	(107)
Al <sub>2</sub> (SO <sub>4</sub> ) <sub>3</sub>	(107, 169, † 207, 343)
Al(NO <sub>3</sub> ) <sub>3</sub>	(107)
Al <sub>2</sub> (SO <sub>4</sub> ) <sub>3</sub> ·(NH <sub>4</sub> ) <sub>2</sub> SO <sub>4</sub> ·24H <sub>2</sub> O	(103, 169 †)
FeCl <sub>3</sub>	(5)
FeCl <sub>2</sub>	(5, 50, † 169, † 326)
FeBr <sub>3</sub>	(5, 326)
FeSO <sub>4</sub>	(5, 166 †)
Fe <sub>2</sub> (SO <sub>4</sub> ) <sub>3</sub>	(5, 489 †)

Formula	Solvents and literature
Fe(NO <sub>3</sub> ) <sub>3</sub>	(5)
Fe <sub>2</sub> (SO <sub>4</sub> ) <sub>3</sub> ·(NH <sub>4</sub> ) <sub>2</sub> SO <sub>4</sub> ·24H <sub>2</sub> O	(103, 345 †)
Fe(C <sub>2</sub> H <sub>3</sub> O <sub>2</sub> ) <sub>2</sub>	(50 †)
ScCl <sub>3</sub>	With chlorides of Yb, Yt, La (103)
YCl <sub>3</sub>	With chlorides of Sc, Yb, La (103)
LaCl <sub>3</sub>	With chlorides of Sc, Yb, Yt (103)
La(NO <sub>3</sub> ) <sub>3</sub>	(103)
NdCl <sub>3</sub>	(342, 343); EtOH (344)
NdBr <sub>3</sub>	(342)
Nd <sub>2</sub> (SO <sub>4</sub> ) <sub>3</sub>	(342)
Nd(NO <sub>3</sub> ) <sub>3</sub>	(103, 342, 343)
Nd(C <sub>2</sub> H <sub>3</sub> O <sub>2</sub> ) <sub>3</sub>	(342)
(Pr, Nd)(NO <sub>3</sub> ) <sub>3</sub>	(103)
YbCl <sub>3</sub>	With chlorides of Sc, Yt, La (103)
MgCl <sub>2</sub>	(107, 207, 343, 344, 582)
MgBr <sub>2</sub>	(344, 582)
MgSO <sub>4</sub>	(344, 582)
Mg(NO <sub>3</sub> ) <sub>2</sub>	(107); EtOH, Me <sub>2</sub> CO (344)
CaCl <sub>2</sub> ·2H <sub>2</sub> O	(207, 343, 344, 582)
SrCl <sub>2</sub>	(107)
LiOH	(107, 200)
NaOH	(107, 200)
NaCl	(107, 166, † 347 †)
Na <sub>2</sub> S <sub>2</sub> O <sub>3</sub>	(107)
NaNO <sub>3</sub>	(344)
Na <sub>2</sub> O·SiO <sub>2</sub>	(103, 489)
Na <sub>2</sub> B <sub>4</sub> O <sub>7</sub>	(103)
KOH	(107, 200 †)
KCl	(91, 207, † 343, † 344, † 582 †)
KNO <sub>3</sub>	(343, † 489 †)
KMnO <sub>4</sub>	(103, 345 †)
K <sub>2</sub> Fe(CN) <sub>6</sub>	(50 †)
K <sub>4</sub> Fe(CN) <sub>6</sub>	(50 †)
K <sub>2</sub> Ni(SO <sub>4</sub> ) <sub>2</sub>	(50 †)
K <sub>2</sub> CrO <sub>4</sub>	(50, † 53 †)
K <sub>2</sub> Cr <sub>2</sub> O <sub>7</sub>	(50, † 166 †)
Cr <sub>2</sub> (SO <sub>4</sub> ) <sub>3</sub> ·K <sub>2</sub> SO <sub>4</sub> ·24H <sub>2</sub> O	(50, † 106 †)
KCr(C <sub>2</sub> O <sub>4</sub> ) <sub>2</sub>	(166 †)
Al <sub>2</sub> (SO <sub>4</sub> ) <sub>3</sub> ·K <sub>2</sub> SO <sub>4</sub> ·24H <sub>2</sub> O	(103, 148, † 169 †)
CsOH	(200)

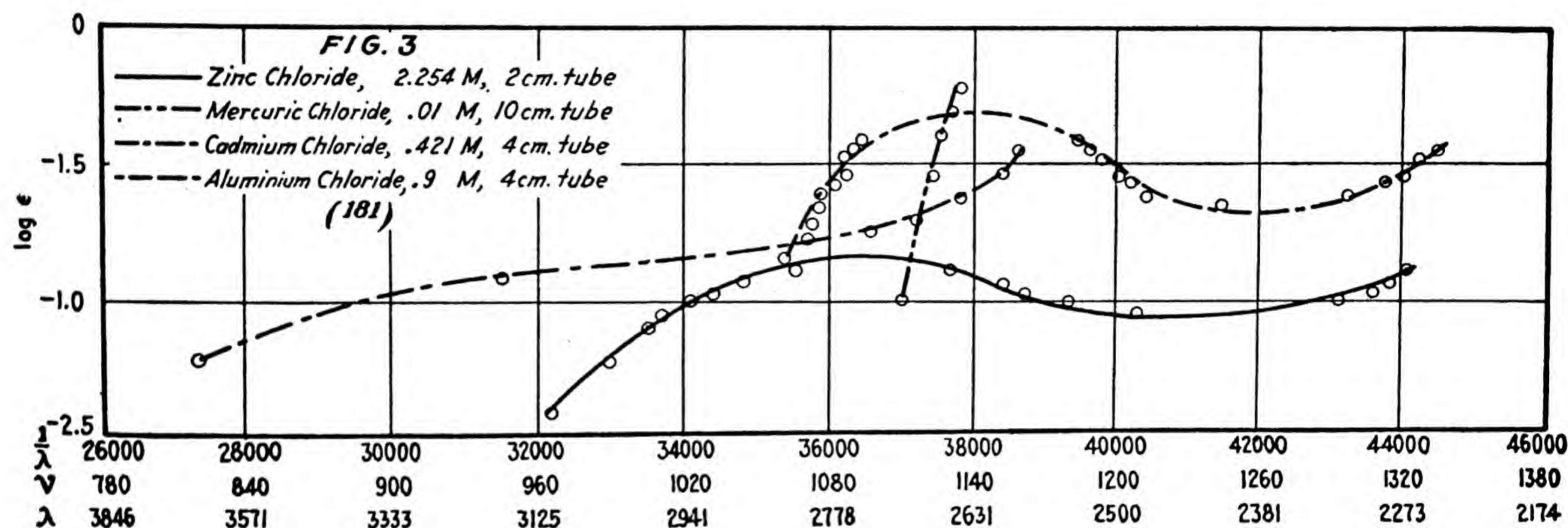
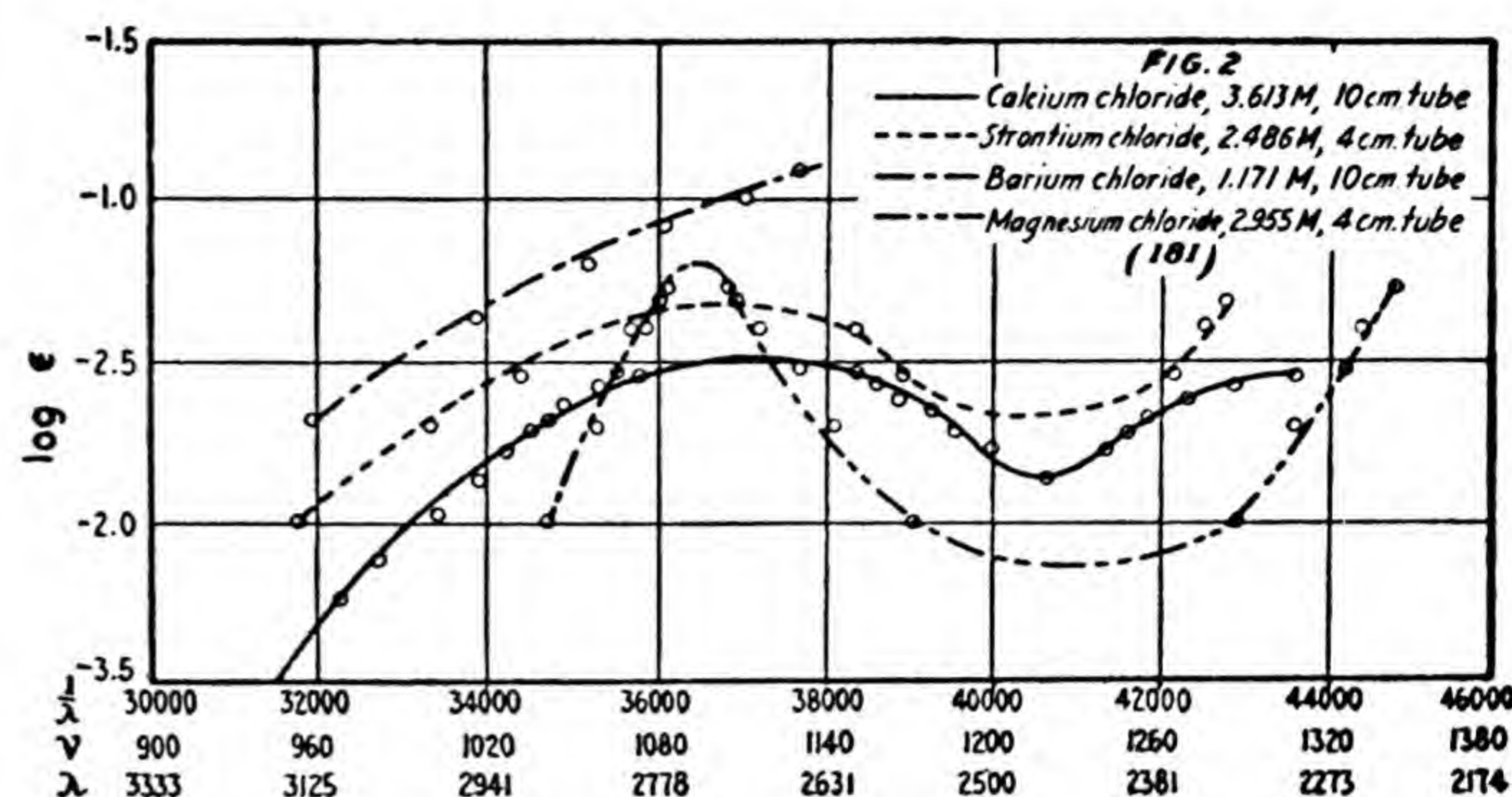
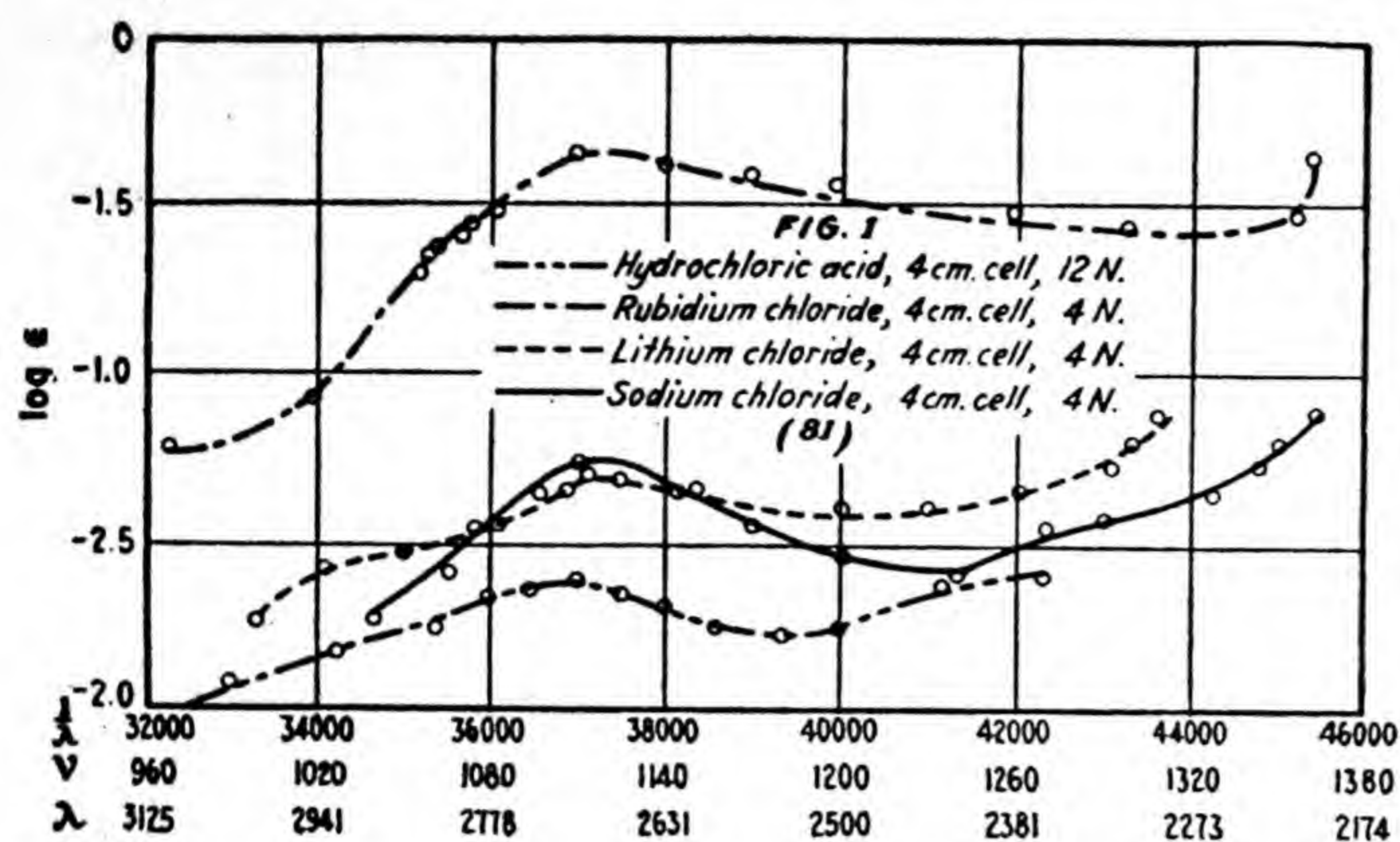
## Ultra-violet and Visible

H <sub>2</sub> O <sub>2</sub>	(552)
HCl	(81 †); cf. Fig. 1
HClO	(562, 568)
HBrO	(568)
HBrO <sub>2</sub>	(568, 660)
I	(176.2); CCl <sub>4</sub> (83.2, 94, 612); CS <sub>2</sub> , Ac <sub>2</sub> O, PhMe, C <sub>6</sub> H <sub>5</sub> Me <sub>2</sub> (485); CHCl <sub>3</sub> (94, 116, 387, 485, 612, 646); MeOH, H <sub>2</sub> O (612); EtOH (83.2, 94, 116, 386, 387, 485, 611, 612); PrOH, <i>iso</i> -PrOH, <i>sec</i> -BuOH, NaOH (623); AcEt (646); C <sub>6</sub> H <sub>6</sub> (94, 485, 646); C <sub>6</sub> H <sub>14</sub> (116, 387, 646); H <sub>2</sub> O + KI (83.2); Et <sub>2</sub> O (116, 387)
HIO <sub>3</sub>	(182, 568, 660 †)
S	CCl <sub>4</sub> , CS <sub>2</sub> , C <sub>6</sub> H <sub>6</sub> (654)
H <sub>2</sub> S	(659, 660 †)
H <sub>2</sub> SO <sub>3</sub>	(19, † 174, † 182, † 567, 567, 660, 661); cf. Fig. 7
H <sub>2</sub> SO <sub>4</sub>	(471.5 †); metallic salts: (114 †)
HNO <sub>2</sub>	(182, † 660)



Formula	Solvents and literature	Formula	Solvents and literature
Ultra-violet and Visible.—(Continued)			
HNO <sub>3</sub>	(182†); P (564); H <sub>2</sub> O (562, 563, 564); Et <sub>2</sub> O (562, 563, 564); EtOH (562, 563); Vap. (564)	CuSO <sub>4</sub>	(87,† 221, 452†); cf. Fig. 5
NH <sub>2</sub> OH	(25†)	Cu(NO <sub>3</sub> ) <sub>2</sub>	(163, 561, 566); EtOH, Me <sub>2</sub> CO (332); cf. Fig. 6
NH <sub>2</sub> NO <sub>2</sub>	EtOH (25)	Cu(NO <sub>3</sub> ) <sub>2</sub> .6NH <sub>3</sub>	(163)
NH <sub>4</sub> NO <sub>3</sub>	(561)	CuCl <sub>2</sub> .6NH <sub>3</sub>	(488)
NH <sub>2</sub> OH.HCl	H <sub>2</sub> O (276†)	Cu(HONO.SO <sub>3</sub> )	H <sub>2</sub> SO <sub>4</sub> (25)
NH <sub>4</sub> Br	(81†)	Cu salts	H <sub>2</sub> O, EtOH, CHCl <sub>3</sub> (168)
NO <sub>2</sub> .SO <sub>3</sub> H	H <sub>2</sub> SO <sub>4</sub> (25)	Cu (complex salts)	(87,† 587, 589, 590)
HONO.SO <sub>3</sub> H	(25†)	Ag <sub>2</sub> SO <sub>4</sub>	(272†)
NH <sub>2</sub> .SO <sub>3</sub> H	H <sub>2</sub> O (25)	AgNO <sub>3</sub>	(272,† 561, 562, 566, 657†)
NH <sub>4</sub> .HSO <sub>3</sub>	(174)	Ag (complex salts)	(587, 588)
H <sub>3</sub> AsO <sub>3</sub>	(182,† 659, 660†)	Au sols	(49.5, 483†)
H <sub>3</sub> AsO <sub>4</sub>	(182†)	Ir (complex salts)	(4, 408)
AsCl <sub>3</sub>	(422†)	H <sub>2</sub> PtCl <sub>6</sub>	H <sub>2</sub> O, EtOH (221, 230)
As <sub>2</sub> S <sub>5</sub>	(79†)	CuPtCl <sub>6</sub> .18NH <sub>3</sub>	(488)
SbCl <sub>3</sub>	(422†)	Pt (complex salts)	(408, 587, 588)
Sb (complex salts)	(407)	Rh (complex salts)	(408)
BiCl <sub>3</sub>	(422†); in various solvents (569)	MnCl <sub>2</sub>	(340)
Bi(ClO <sub>4</sub> ) <sub>3</sub>	(566, 569)	MnCl <sub>3</sub>	(340)
BiBr <sub>3</sub>	H <sub>2</sub> O, (+HBr), Et <sub>2</sub> O (569)	MnCl <sub>4</sub>	(340)
Bi <sub>2</sub> (SO <sub>4</sub> ) <sub>3</sub>	H <sub>2</sub> SO <sub>4</sub> (569)	MnSO <sub>4</sub>	(340)
Bi(NO <sub>3</sub> ) <sub>3</sub>	(566)	Mn <sub>2</sub> (SO <sub>4</sub> ) <sub>3</sub>	(340)
Bi (complex salts)	(569)	Mn(NO <sub>3</sub> ) <sub>3</sub>	(561)
Si(C <sub>6</sub> H <sub>5</sub> ) <sub>4</sub>	CHCl <sub>3</sub> (522)	Zn(MnO <sub>4</sub> ) <sub>2</sub>	(458, 503)
Si(OH) <sub>2</sub> (C <sub>6</sub> H <sub>5</sub> CH <sub>2</sub> ) <sub>2</sub>	EtOH, (+alk.) (551)	Mn (complex salts)	(407)
[SiOH(C <sub>6</sub> H <sub>5</sub> CH <sub>2</sub> ) <sub>2</sub> ] <sub>2</sub> O	EtOH (551)	Fe (complex salts)	(88, 407, 408)
[SiO(C <sub>6</sub> H <sub>5</sub> CH <sub>2</sub> ) <sub>2</sub> ] <sub>3</sub>	CHCl <sub>3</sub> (551)	CoF <sub>2</sub>	(320, 328, 330)
Si <sub>3</sub> (OH) <sub>2</sub> [(C <sub>6</sub> H <sub>5</sub> CH <sub>2</sub> ) <sub>2</sub> ] <sub>3</sub> O <sub>2</sub>	EtOH (551)	CoCl <sub>2</sub>	(330); EtOH (110, 227, 332); Me <sub>2</sub> CO (332); H <sub>2</sub> O (110); MeOH (408)
Ge	(485.5†)	CoBr <sub>2</sub>	(110, 328, 330); EtOH, Me <sub>2</sub> CO (332)
Sn (complex salts)	(587, 588)	CoI <sub>2</sub>	(328, 330)
Pb(NO <sub>3</sub> ) <sub>2</sub>	(272, 561)	CoSO <sub>4</sub>	(320, 328, 330)
Th(NO <sub>3</sub> ) <sub>4</sub>	(272,† 561, 566)	Co(NO <sub>3</sub> ) <sub>2</sub>	(162, 320, 328, 330, 460,† 561); EtOH, Me <sub>2</sub> CO (332)
ThCl <sub>4</sub>	(272†)	Co (complex salts)	(407, 408, 420, 444, 470, 492, 585, 586, 591, 643); CHCl <sub>3</sub> (123†)
Tl <sub>2</sub> SO <sub>4</sub>	(272†)	NiCl <sub>2</sub>	(327,† 328,†); EtOH, Me <sub>2</sub> CO (332†)
TlNO <sub>3</sub>	(272,† 566)	NiBr <sub>2</sub>	(327,† 328,† 332†)
ZnCl <sub>2</sub>	(181†); cf. Fig. 3	NiI <sub>2</sub>	(327,† 328†)
Zn (complex salts)	(587, 588)	NiSO <sub>4</sub>	(327,† 328†)
CdCl <sub>2</sub>	(181†); cf. Fig. 3	Ni(NO <sub>3</sub> ) <sub>2</sub>	(164, 327,† 328,† 332,† 561)
Cd (complex salts)	(587, 588)	Ni(CO) <sub>4</sub>	(408)
Hg	(176.2†)	Ni (complex salts)	(470, 589, 590)
HgCl <sub>2</sub>	(113, 181,† 390); cf. Fig. 3	H <sub>2</sub> CrO <sub>4</sub>	(221)
Hg(ClO <sub>4</sub> ) <sub>2</sub>	(390)	Cr <sub>2</sub> (SO <sub>4</sub> ) <sub>3</sub>	(197)
HgBr <sub>2</sub>	(113, 390)	Cr (complex salts)	(88, 167, 407, 589, 590)
HgI <sub>2</sub>	(113, 390)	UCl <sub>2</sub>	Various solvents (459,† 461†)
HgNO <sub>3</sub>	(113, 562, 566)	USO <sub>4</sub>	Various org. solvents (459†)
Hg(NO <sub>3</sub> ) <sub>2</sub>	(113)	U (complex salts)	(449,† 450,† 451)
Hg(CH <sub>3</sub> ) <sub>2</sub>	Et <sub>2</sub> O (113)	AlCl <sub>3</sub>	(179†); cf. Fig. 3
Hg(C <sub>2</sub> H <sub>5</sub> ) <sub>2</sub>	EtOH (113)	Al (complex salts)	(588)
Hg(C <sub>6</sub> H <sub>5</sub> ) <sub>2</sub>	EtOH (386); CHCl <sub>3</sub> (537)	Ce(NO <sub>3</sub> ) <sub>3</sub>	(566)
Hg(C <sub>6</sub> H <sub>5</sub> CH <sub>2</sub> ) <sub>2</sub>	CHCl <sub>3</sub> (537)	PrCl <sub>3</sub>	(4, 15,† 48,† 321,† 662)
HgCH <sub>3</sub> Cl	(390); EtOH (113)	Pr <sub>2</sub> (SO <sub>4</sub> ) <sub>3</sub>	(15†)
HgC <sub>2</sub> H <sub>5</sub> Cl	(390); EtOH (113)	Pr(NO <sub>3</sub> ) <sub>3</sub>	(15,† 321†)
HgCH <sub>3</sub> Br	EtOH (113)	NdCl <sub>3</sub>	(4,† 15,† 47,† 49,† 110, 173,† 321, 596,† 662)
HgCH <sub>3</sub> I	EtOH (113)	Nd <sub>2</sub> (SO <sub>4</sub> ) <sub>3</sub>	(15)
HgC <sub>2</sub> H <sub>5</sub> I	EtOH (113)	Nd(NO <sub>3</sub> ) <sub>3</sub>	(15, 47,† 321†)
HgN(CH <sub>3</sub> CO) <sub>2</sub> OH	(390)	Di salts	(4,† 529†)
Hg(C <sub>2</sub> H <sub>5</sub> ONH) <sub>2</sub>	(390)	SaCl <sub>3</sub>	(662)
Hg (complex salts)	(113, 341, 587)	Sa(NO <sub>3</sub> ) <sub>3</sub>	(499†)
CuCl <sub>2</sub>	(87,† 110, 178,† 179, 181†); EtOH, Me <sub>2</sub> CO (332); cf. Fig. 5		
Cu(ClO <sub>4</sub> ) <sub>2</sub>	(221)		
CuBr <sub>2</sub>	(87†); EtOH, Me <sub>2</sub> CO (332)		

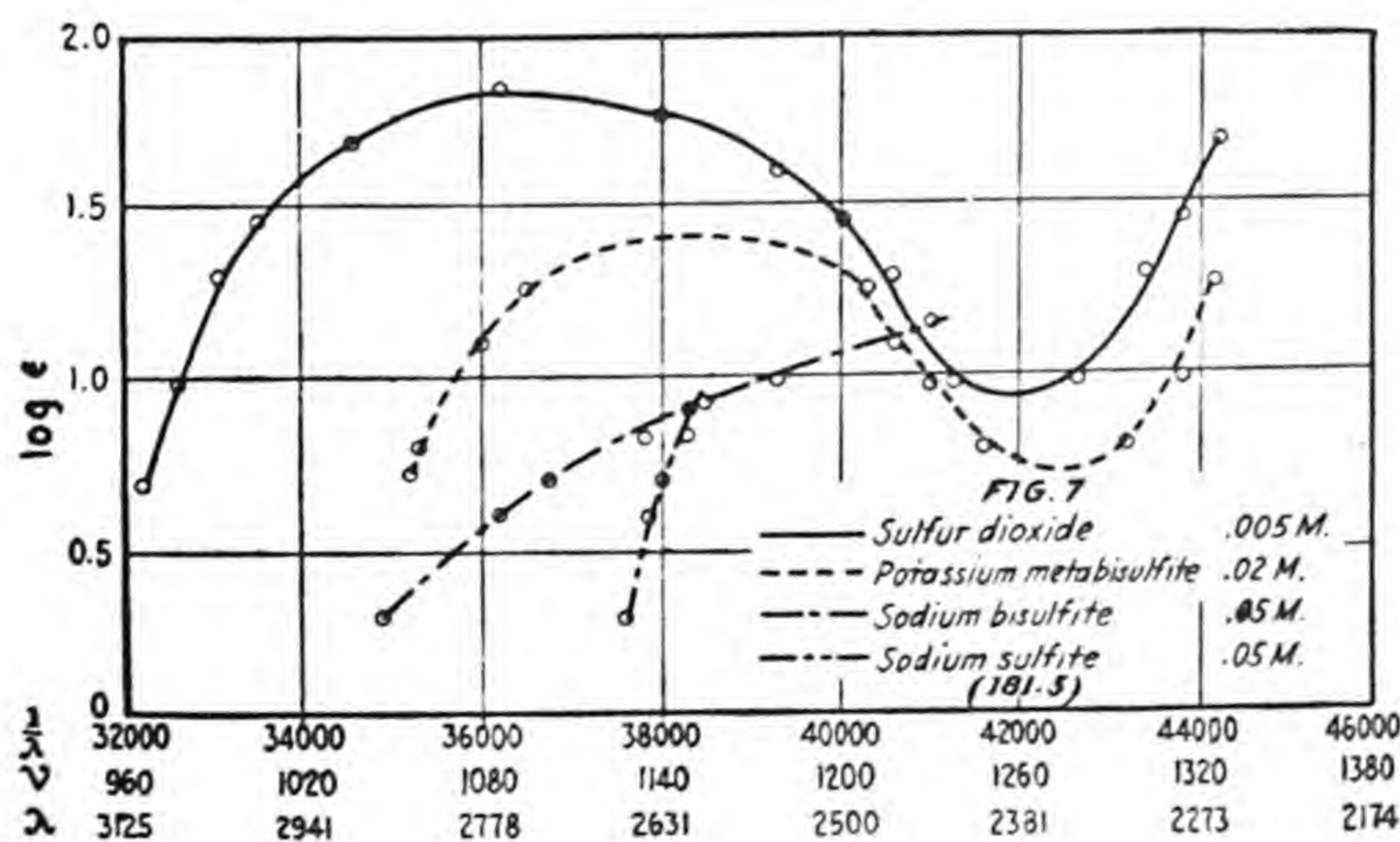
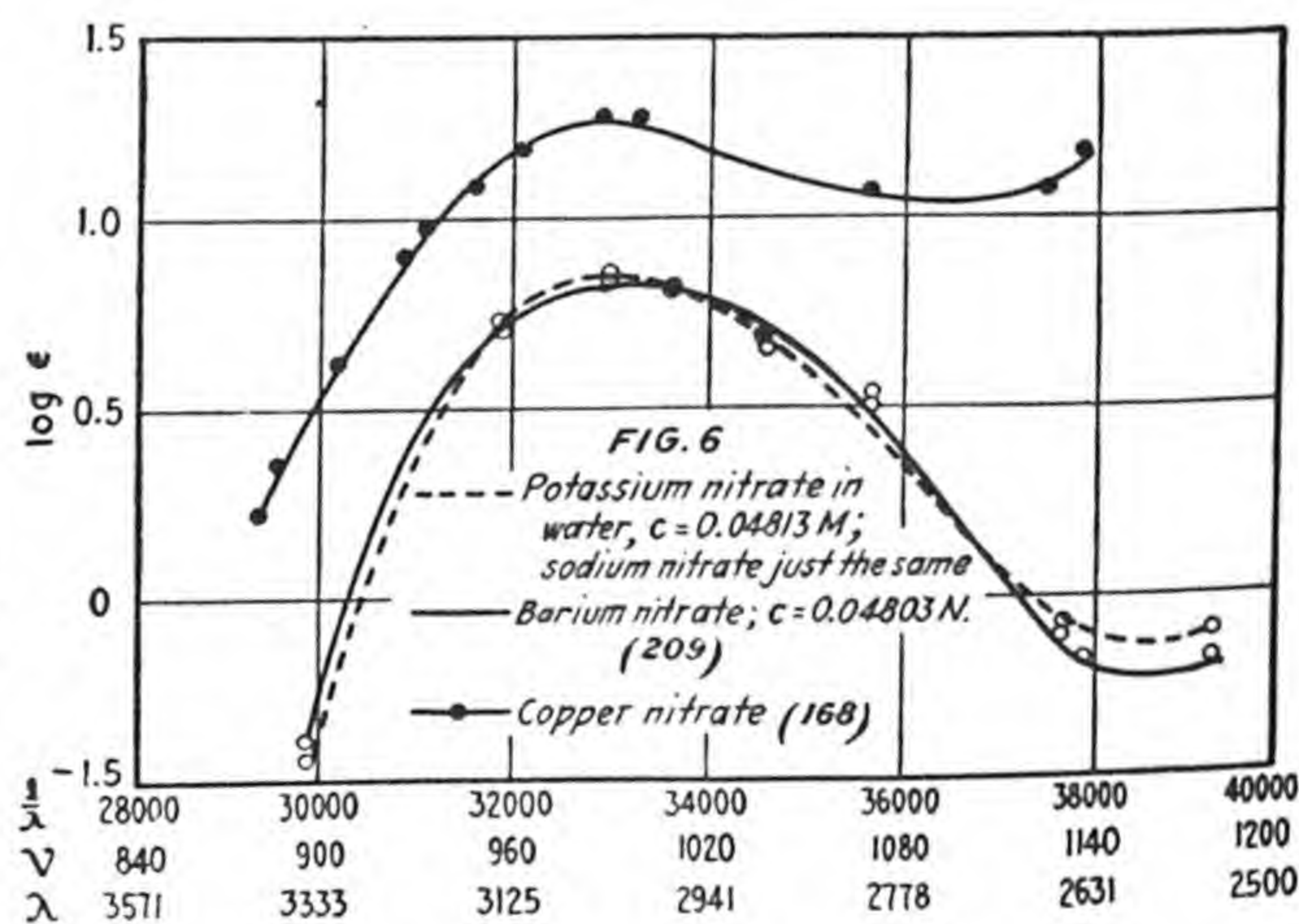
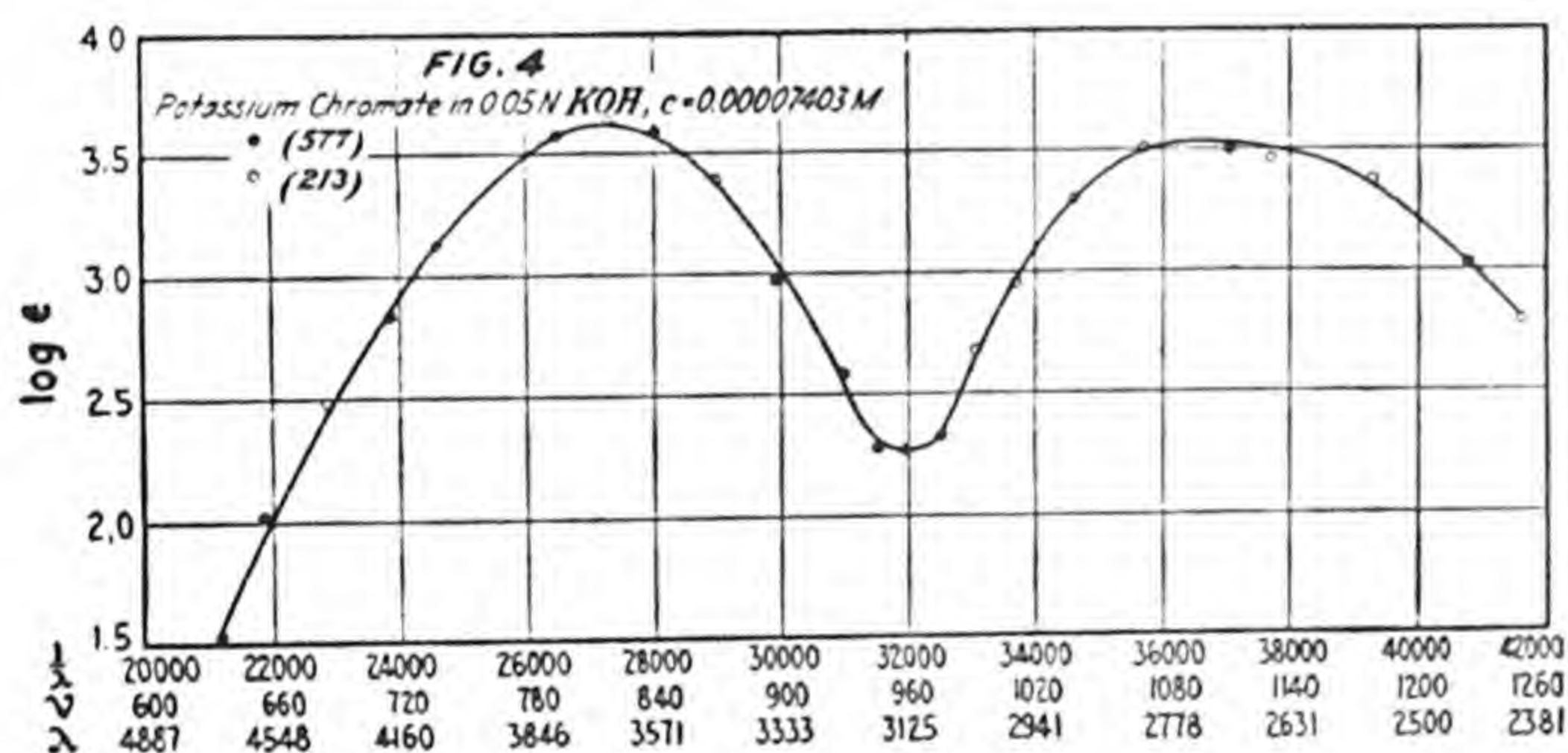
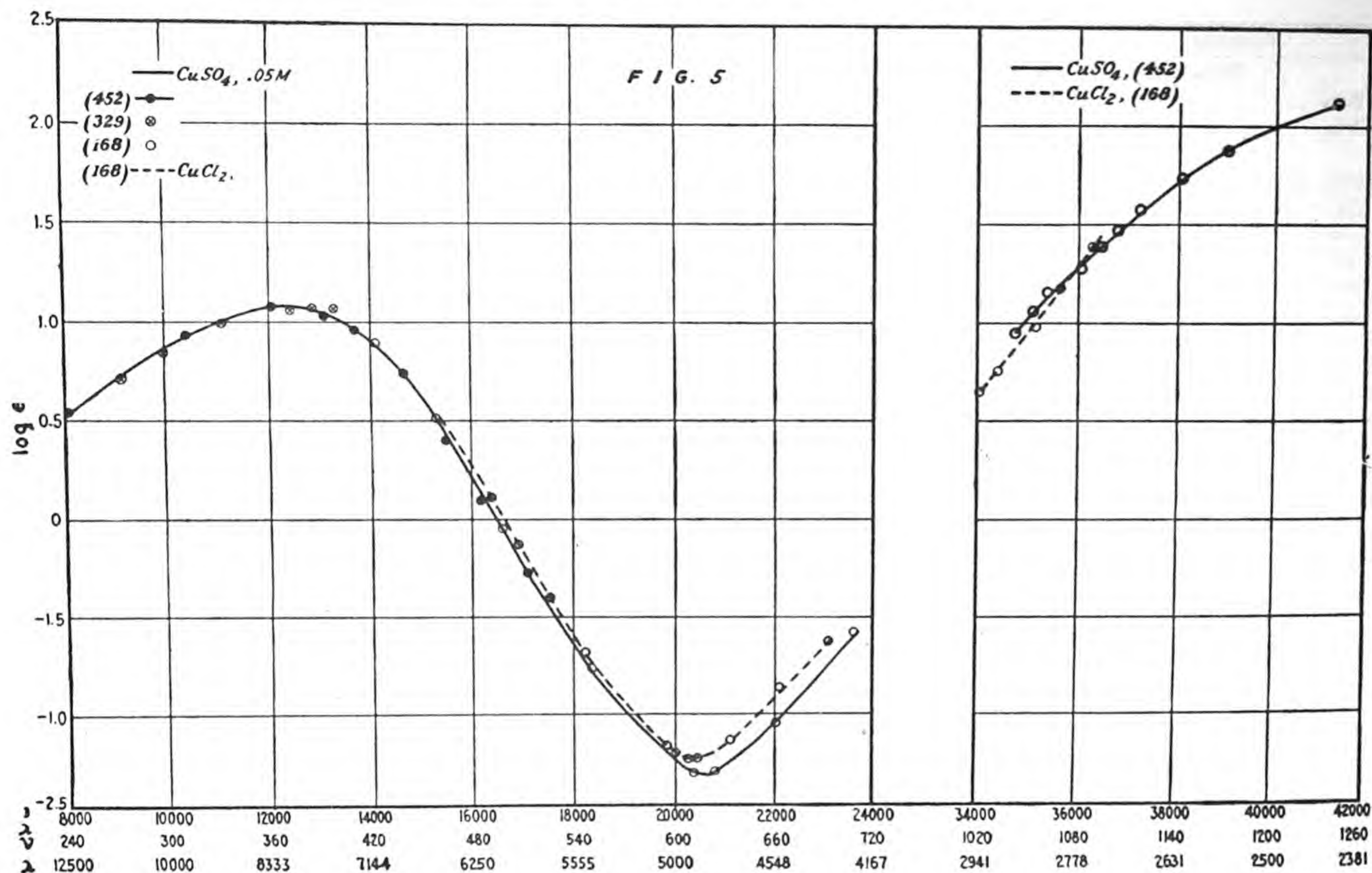




Formula	Solvents and literature
<b>Ultra-violet and Visible.—(Continued)</b>	
Eu(NO <sub>3</sub> ) <sub>3</sub>	(498, 499)
DyCl <sub>3</sub>	(662)
HoCl <sub>3</sub>	(662)
Ho(NO <sub>3</sub> ) <sub>3</sub>	(322 †)
ErCl <sub>3</sub>	(662)
TmCl <sub>3</sub>	(662)
Be(NO <sub>3</sub> ) <sub>2</sub>	(566)
Mg	MeNH <sub>2</sub> (188 †); liq. NH <sub>3</sub> (187, † 188 †)
MgCl <sub>2</sub>	(181, † 495 †); cf. Fig. 2
Mg(NO <sub>3</sub> ) <sub>2</sub>	EtOH (563)
Ca	MeNH <sub>2</sub> , liq. NH <sub>3</sub> (188 †)
CaCl <sub>2</sub>	(181, † 495 †); cf. Fig. 2
Ca(NO <sub>3</sub> ) <sub>2</sub>	(561); EtOH, H <sub>2</sub> O (240)
Ca(MnO <sub>4</sub> ) <sub>2</sub>	(2 †); H <sub>2</sub> O, Me <sub>2</sub> CO, MeOH, C <sub>6</sub> H <sub>5</sub> N, Me <sub>2</sub> CNOH, EtOH (458 †)
Ca <sub>2</sub> Fe(CN) <sub>6</sub>	(230)
SrCl <sub>2</sub>	(181, † 495 †); cf. Fig. 2
Sr(NO <sub>3</sub> ) <sub>2</sub>	(561)
BaCl <sub>2</sub>	(181, † 495 †); cf. Fig. 2
Ba(NO <sub>3</sub> ) <sub>2</sub>	(182, † 209, † 561); cf. Fig. 6
Ba(MnO <sub>4</sub> ) <sub>2</sub>	(503); H <sub>2</sub> O, various solvents (458)
Li	MeNH <sub>2</sub> , liq. NH <sub>3</sub> (188 †)
LiCl	(81, † 544); cf. Fig. 1
LiBr	(544)
LiI	(81 †)

Formula	Solvents and literature
LiNO <sub>3</sub>	(561)
Na	MeNH <sub>2</sub> (188 †); liq. NH <sub>3</sub> (187, † 188 †)
NaCl	(81, † 544); cf. Fig. 1
NaClO	(380, † 562, 568)
NaClO <sub>2</sub>	(568)
NaBr	(81, † 544)
NaBrO	(568)
NaBrO <sub>3</sub>	(568, 660 †)
NaI	(81, † 544)
NaIO <sub>3</sub>	(568, 660 †)
Na <sub>2</sub> S	(659, 660 †)
Na <sub>2</sub> SO <sub>3</sub>	(19, † 182, † 562, 660, 661); H <sub>2</sub> O, H <sub>2</sub> SO <sub>4</sub> (567); cf. Fig. 7
NaHS	(660 †)
NaHSO <sub>3</sub>	(174, † 182, † 562, 567, 660); cf. Fig. 7
NaNO <sub>2</sub>	(113, 660)
NaNO <sub>3</sub>	(113, 182, † 209, † 561, 562, 563); cf. Fig. 6
(NaON) <sub>2</sub> O	H <sub>2</sub> O (25)
Na <sub>2</sub> AsO <sub>3</sub>	(659, 660 †)
Na <sub>2</sub> AsO <sub>4</sub>	(182 †)
NaH <sub>2</sub> AsO <sub>4</sub>	(659, † 660 †)
Na <sub>2</sub> HAsO <sub>4</sub>	(659, † 660 †)
Na <sub>2</sub> PtCl <sub>6</sub>	(221, 230)
Na <sub>4</sub> Fe(CN) <sub>6</sub>	(230)





Formula	Solvents and literature
Ultra-violet and Visible.—(Continued)	
K	$\text{MeNH}_3$ , liq. $\text{NH}_3$ (188†)
KOH	(471.5†)
KBr	(81†); $\text{H}_2\text{O} + \text{Na}_2\text{S}_2\text{O}_3$ (83.2)
KI	(81,† 544); $\text{H}_2\text{O} + \text{Na}_2\text{S}_2\text{O}_3$ (83.2)
KIO <sub>3</sub>	(182†)
K <sub>2</sub> SO <sub>4</sub>	(471.5†)
K <sub>2</sub> S <sub>2</sub> O <sub>6</sub>	(19,† 567); cf. Fig. 7
K <sub>2</sub> S <sub>2</sub> O <sub>8</sub>	$\text{H}_2\text{O}$ , $\text{H}_2\text{SO}_4$ (471.5†)
KHSO <sub>3</sub>	(19,† 174†)



Formula	Solvents and literature
<b>Ultra-violet and Visible.—(Continued)</b>	
KNO <sub>3</sub>	(182†)
KNO <sub>2</sub>	(182,† 209,† 561, 562, 563, 565, 625, 657); cf. Fig. 6
(KSO <sub>3</sub> ) <sub>2</sub> NO	H <sub>2</sub> O (25)
(KSO <sub>3</sub> ) <sub>2</sub> NOH	H <sub>2</sub> O (25)
K <sub>2</sub> AsO <sub>4</sub>	(182†)
K <sub>2</sub> PtF <sub>6</sub>	(580)
K <sub>2</sub> PtCl <sub>4</sub>	(408)
K <sub>2</sub> PtCl <sub>6</sub>	(221, 408, 580)
K <sub>2</sub> PtBr <sub>6</sub>	(580)
K <sub>2</sub> PtI <sub>6</sub>	(580)
KMnO <sub>4</sub>	(2, 3, 193, 208,† 340, 503, 547, 645†); H <sub>2</sub> SO <sub>4</sub> , MeOH, Me <sub>2</sub> CO, AcOH, C <sub>2</sub> H <sub>5</sub> N, KOH (228); various solvents (458)
K <sub>2</sub> MnO <sub>4</sub>	(340)
KCo(NH <sub>3</sub> ) <sub>2</sub> (NO <sub>2</sub> ) <sub>4</sub>	H <sub>2</sub> O, MeOH, C <sub>2</sub> H <sub>5</sub> N (221)
K <sub>2</sub> Co(CNS) <sub>4</sub>	(227)
K <sub>2</sub> Co(CN) <sub>6</sub>	(407, 588)
K <sub>2</sub> CrO <sub>4</sub>	(221, 574†); KOH (213†); cf. Fig. 4
K <sub>2</sub> Cr <sub>2</sub> O <sub>7</sub>	(221)
K <sub>2</sub> Cr(CN) <sub>6</sub>	(407)
K <sub>2</sub> Fe(CN) <sub>6</sub>	(177, 407, 492)
K <sub>4</sub> Fe(CN) <sub>6</sub>	(177, 221, 230, 492, 588)
RbCl	(81†); cf. Fig. 1
RbI	(81†)
RbHSO <sub>4</sub>	(174†)
Cs	MeNH <sub>2</sub> (188†)
CsI	(81†)

# ORGANIC COMPOUNDS AND THEIR INORGANIC SALT-DERIVATIVES

**Scope.**—The following bibliographic index serves also as an index to the numerical data, given as curves, on p. 359–379. The bibliography includes all organic substances, exclusive of dyes, whose absorption spectra have been measured. In the infra-red region all measurements are quantitative; in the ultra-violet a very large proportion are purely qualitative and are based on the change of the limits of absorption with the length of the path.

**Arrangement.**—The organic compounds are arranged according to the “C-arrangement” and their inorganic salt-derivatives are grouped immediately after the parent compound. Substances to which a formula cannot be assigned are listed at the end of each section (p. 334 and p. 356).

For reference texts, see (297, 348). The solvent is ethyl alcohol unless otherwise stated.

## C-Table.—C-Arrangement (v. Vol. III, p. viii)

Formula	Name, solvents and literature
<b>Infra-red</b>	
CCl <sub>2</sub> O	Phosgene (437)
CCl <sub>2</sub> S	Thiophosgene (437†)
CCl <sub>4</sub>	Carbon tetrachloride (101, 126,† 169,† 336,† 347,† 501†)
COS	Carbonyl sulfide (346)
CS <sub>2</sub>	Carbon disulfide (6, 7, 12, 101, 126,† 169,† 336,† 347,† 501,† 555†); Vap. (6,† 7, 9, 12, 556,† 557†)
CHBr <sub>3</sub>	Bromoform (152, 169,† 336,† 347†)
CHCl <sub>3</sub>	Chloroform (1,† 52.4, 101, 149, 151,† 152, 169,† 336,† 347,† 437, 627); Vap. (126,† 149, 373†)
CHI <sub>3</sub>	Iodoform (101)

Formula	Name, solvents and literature
CHN	Hydrogen cyanide (46, 85, 313†); Vap. (85)
CH <sub>2</sub> Br <sub>2</sub>	Methylene bromide (152)
CH <sub>2</sub> Cl <sub>2</sub>	Methylene chloride (152, 169,† 336†)
CH <sub>2</sub> I <sub>2</sub>	Methylene iodide (152, 169,† 336†)
CH <sub>2</sub> O <sub>2</sub>	Formic acid (1†); Vap. (373†)
CH <sub>3</sub> Cl	Methyl chloride: Vap. (556,† 557†)
CH <sub>3</sub> I	Methyl iodide (1,† 100,† 101, 152, 169,† 336,† 501,† 502)
CH <sub>3</sub> NO <sub>2</sub>	Nitromethane (101)
CH <sub>4</sub>	Methane: Vap. (6,† 7, 10,† 11, 100,† 101, 108,† 109,† 124,† 125,† 126,† 313,† 541,† 556,† 557†)
CH <sub>3</sub> O	Methyl alcohol (1,† 8, 73,† 169,† 345,† 347,† 375,† 376,† 377,† 501,† 502,† 652); Vap. (10,† 373†)
C <sub>2</sub> Cl <sub>4</sub>	Tetrachloroethylene (101, 169†)
(CN) <sub>2</sub>	Cyanogen: Vap. (85, 556,† 557†)
C <sub>2</sub> HCl <sub>3</sub>	Trichloroethylene (592.2)
C <sub>2</sub> HCl <sub>2</sub> O <sub>2</sub>	Trichloroacetic acid (52.4)
C <sub>2</sub> H <sub>2</sub>	Acetylene: Vap. (6,† 9,† 85, 100,† 101, 126,† 313,† 349,† 376,† 556,† 557†)
C <sub>2</sub> H <sub>2</sub> Cl <sub>2</sub>	Dichloroethylene (592.2)
C <sub>2</sub> H <sub>2</sub> Cl <sub>2</sub> O <sub>2</sub>	Dichloroacetic acid (52.4)
C <sub>2</sub> H <sub>2</sub> Cl <sub>4</sub>	Tetrachloroethane (592.2, 627)
C <sub>2</sub> H <sub>2</sub> ClO <sub>2</sub>	Chloroacetic acid (52.4)
C <sub>2</sub> H <sub>2</sub> Cl <sub>3</sub> O <sub>2</sub>	Chloral hydrate (102)
C <sub>2</sub> H <sub>3</sub> N	Acetonitrile (101)
C <sub>2</sub> H <sub>3</sub> NS	Methyl isothiocyanate (100, 101)
C <sub>2</sub> H <sub>4</sub>	Ethylene (7, 9,† 100, 101, 126,† 313,† 349, 436, 556, 557†)
C <sub>2</sub> H <sub>4</sub> Br <sub>2</sub>	Ethylene bromide (101, 152, 169†)
C <sub>2</sub> H <sub>4</sub> Cl <sub>2</sub>	Ethylene chloride (152, 169,† 336,† 592.2)
C <sub>2</sub> H <sub>4</sub> Cl <sub>2</sub>	1, 1-Dichloroethane (336†)
C <sub>2</sub> H <sub>4</sub> O	Acetaldehyde (1,† 169,† 376,† 652)
C <sub>2</sub> H <sub>4</sub> O <sub>2</sub>	Acetic acid (1,† 52.4, 101)
C <sub>2</sub> H <sub>5</sub> Br	Ethyl bromide (1,† 152, 169,† 336†)
C <sub>2</sub> H <sub>5</sub> Cl	Ethyl chloride (152)
C <sub>2</sub> H <sub>5</sub> I	Ethyl iodide (1,† 100,† 101, 152, 169,† 336,† 502†); Vap. (349†)
C <sub>2</sub> H <sub>5</sub> NO	Nitroethane (101)
C <sub>2</sub> H <sub>5</sub> NO <sub>2</sub>	Ethyl nitrate (1†)
C <sub>2</sub> H <sub>6</sub>	Ethane (100,† 101, 313, 375†)
C <sub>2</sub> H <sub>6</sub> O	Ethyl alcohol (1,† 8, 73,† 101, 169,† 336,† 345,† 347,† 377,† 417, 501,† 555,† 558,† 592.2, 652, 653†); Vap. (373,† 556,† 557,† 558†); Na salt (652)
C <sub>2</sub> H <sub>6</sub> O	Methyl ether (101, 501,†); Vap. (9,† 100,† 313)
C <sub>2</sub> H <sub>6</sub> O <sub>2</sub>	Glycol (169,† 652)
C <sub>2</sub> H <sub>6</sub> S	Ethylmercaptan (101, 347†)
C <sub>2</sub> H <sub>7</sub> N	Ethylamine (169†)
C <sub>2</sub> H <sub>8</sub> N <sub>2</sub>	Ethylenediamine (169†)
C <sub>2</sub> H <sub>4</sub> O	Acrolein (437†)
C <sub>2</sub> H <sub>5</sub> Br	Allyl bromide (169†)
C <sub>2</sub> H <sub>5</sub> Cl	Allyl chloride (169†)
C <sub>2</sub> H <sub>5</sub> I	Allyl iodide (169†)
C <sub>2</sub> H <sub>5</sub> N	Ethyl cyanide (101)
C <sub>2</sub> H <sub>5</sub> NS	Ethyl isothiocyanate (100, 101†)
C <sub>2</sub> H <sub>5</sub> Br <sub>2</sub>	Trimethylene bromide (169†)
C <sub>2</sub> H <sub>5</sub> O	Allyl alcohol (1,† 501,† 652)
C <sub>2</sub> H <sub>5</sub> O	Propionaldehyde (378,† 437)
C <sub>2</sub> H <sub>5</sub> O	Acetone (101, 152, 169,† 374,† 375,† 376,† 378,† 437, 627); Vap. (101)
C <sub>2</sub> H <sub>5</sub> O <sub>2</sub>	Propionic acid (1†)
C <sub>2</sub> H <sub>5</sub> O <sub>2</sub>	Methyl acetate (52.4, 91, 101, 169,† 366,† 376,† 592.2, 652); Vap. (349†)
C <sub>2</sub> H <sub>5</sub> O <sub>2</sub>	Methyl carbonate (101)
C <sub>2</sub> H <sub>7</sub> Br	Propyl bromide (152)
C <sub>2</sub> H <sub>7</sub> I	Propyl iodide (1,† 152)



Formula	Name, solvents and literature	Formula	Name, solvents and literature
<b>Infra-red.—(Continued)</b>			
$C_3H_7I$	Isopropyl iodide (152)	$C_5H_{12}$	Pentane (152, 153); Vap. (556, † 557 †)
$C_3H_8O$	Isopropyl alcohol (1, † 377, 652)	$C_5H_{12}O$	Amyl alcohol (1, † 101, 169, † 347, † 627, 652); Vap. (373)
$C_3H_8O$	Propyl alcohol (1, † 73, † 169, † 345, † 347, † 377, † 627, 652)	$C_5H_{12}O$	Isoamyl alcohol (345, † 377, † 652)
$C_3H_8O_2$	Propyleneglycol (652)	$C_5H_{12}O$	<i>tert.</i> -Amyl alcohol (377, † 652)
$C_3H_8O_3$	Glycerol (1, † 101, 105, 169, 489, 652)	$C_5H_{12}O$	Methyl iso( <i>n</i> -, <i>sec.</i> -, <i>tert.</i> -) butyl ether (592.2)
$C_3H_9N$	<i>n</i> -Propylamine (52.3, 153.3)	$C_5H_{12}O_3$	Ethylglycerol (377 †)
$C_3H_{12}N_6O_3$	Guanidine carbonate (570)	$C_5H_{13}N$	Isoamylamine (52.3, 153.3)
$C_4H_4S$	Thiophene (101)	$C_6H_5Br$	Bromobenzene (1, † 101, 528); Vap. (528)
$C_4H_5N$	Pyrrole (100, 101)	$C_6H_5Cl$	Chlorobenzene (101, † 437, 528); Vap. (528)
$C_4H_5NS$	Allyl isothiocyanate (100, † 101)	$C_6H_5F$	Fluorobenzene (437)
$C_4H_6O_3$	Acetic anhydride (52.4, 169 †)	$C_6H_5I$	Iodobenzene (528); Vap. (528)
$C_4H_6O_5$	Malic acid (102)	$C_6H_5NO_2$	Nitrobenzene (1, † 101, 169, † 627)
$C_4H_8O$	Butyraldehyde (378, † 437 †)	$C_6H_6$	Benzene (1, † 52, 46.5, † 74, 100, 101, 105, 149, 152, 153.2, 169, † 347, † 376, † 436, † 437, 501, 502, 528, 555 †); Vap. (6, † 10, † 149, 373, † 528, 558 †)
$C_4H_8O$	Isobutyraldehyde (437 †)		Phenol (100, † 101)
$C_4H_8O$	Ethyl methyl ketone (378 †)	$C_6H_6O$	Phloroglucinol (102)
$C_4H_8O_2$	Butyric acid (652)	$C_6H_6O_3$	Aniline (1, † 51, 52.1, † 100, 101, 153.2, 153.3, 169, † 367, 436); Vap. (367)
$C_4H_8O_2$	Isobutyric acid (1, 652)	$C_6H_7N$	$\alpha$ -Picoline (100, 101, 595)
$C_4H_8O_2$	Ethyl acetate (169, † 652)	$C_6H_7N$	Ethyl acetoacetate (1, † 376 †)
$C_4H_8O_2$	Methyl propionate (652)	$C_6H_{10}O_3$	Ethyl oxalate (1, † 375, † 376, † 652)
$C_4H_9Br$	Isobutyl bromide (152)	$C_6H_{10}O_4$	Methyl succinate (375 †)
$C_4H_9Cl$	Isobutyl chloride (152)	$C_6H_{10}O_4$	Allyl sulfide (1, † 101)
$C_4H_9I$	Isobutyl iodide (152)	$C_6H_{10}S$	Hexyl iodide (1 †)
$C_4H_9NO_2$	Butyl nitrite (152)	$C_6H_{11}I$	Amyl cyanide (169 †)
$C_4H_{10}$	Butane (100, 101, † 349 †)	$C_6H_{11}N$	Cyclohexane (374, † 376, † 437)
$C_4H_{10}O$	Methyl <i>n</i> -(iso)propyl ether (592.2)	$C_6H_{12}$	Isobutyl methyl ketone (73, † 378 †)
$C_4H_{10}O$	Butyl alcohol (1, † 73, † 347, † 375, † 377, † 592.2, 652); Vap. (373 †)	$C_6H_{12}O$	Caproic acid (100, † 101)
$C_4H_{10}O$	Isobutyl alcohol (1, † 169, † 336, † 345, † 347, † 375, † 377, † 652)	$C_6H_{12}O_2$	Isocaproic acid (101)
$C_4H_{10}O$	<i>sec.</i> -Butyl alcohol (652)	$C_6H_{12}O_2$	Amyl formate (375, † 592.2)
$C_4H_{10}O$	<i>tert.</i> -Butyl alcohol (377 †)	$C_6H_{12}O_2$	Isoamyl formate (652)
$C_4H_{10}O$	Ethyl ether (1, † 101, 152, 169, † 336, † 347, † 373, 555, † 592.2); Vap. (6, † 7, 9, † 11, 12, 100, † 373, 556, † 557, † 558 †)	$C_6H_{12}O_2$	Ethyl butyrate (375, † 592.2, 652)
$C_4H_{10}O_3$	Methylglycerol (377 †)	$C_6H_{12}O_2$	Isobutyl acetate (652)
$C_4H_{10}O_4S$	Ethyl sulfate (101)	$C_6H_{12}O_2$	Methyl valerate (375 †)
$C_4H_{10}S$	Ethyl sulfide (1, † 101)	$C_6H_{12}O_2$	Methyl isovalerate (652)
$C_4H_{11}N$	Diethylamine (169 †)	$C_6H_{12}O_2$	Propyl propionate (375 †)
$C_4H_{11}N$	<i>n</i> -Butylamine (52.3, 153.3)	$C_6H_{12}O_2$	Paraldehyde (1, † 101, 169 †)
$C_5H_4O_2$	Citraconic anhydride (1 †)	$C_6H_{12}O_3$	<i>d</i> -Fructose (102)
$C_5H_5N$	Pyridine (100, 101, 501, † 595)	$C_6H_{12}O_6$	<i>d</i> -Glucose (102)
$C_5H_8O$	Allyl methyl ketone (378 †)	$C_6H_{12}O_6$	Diisopropyl (169 †)
$C_5H_8O$	Ethyl propargyl ether (374 †)	$C_6H_{14}$	Hexane (73, † 101, 152, 169, † 347, † 437)
$C_5H_8O_2$	Acetylacetone (376 †)	$C_6H_{14}O$	Methyldiethyl carbinol (592.2)
$C_5H_8O_4$	Dimethyl malonate (375 †)	$C_6H_{14}O$	Methyl iso( <i>n</i> -, <i>tert.</i> -) amyl ether (592.2)
$C_5H_{10}O$	Isovaleric aldehyde (378 †)	$C_6H_{14}O$	Hexyl alcohol (377 †)
$C_5H_{10}O$	Diethyl ketone (378 †)	$C_6H_{14}O$	Methyl diethylcarbinyl ether (592.2)
$C_5H_{10}O$	Isopropyl methyl ketone (378 †)	$C_6H_{14}O_3$	Propylglycerol (377 †)
$C_5H_{10}O_2$	Valeric acid (1, † 101)	$C_6H_{14}O_6$	Mannitol (102)
$C_5H_{10}O_2$	Butyl formate (375 †)	$C_6H_{15}BrS$	Triethylsulfonium bromide: $C_2H_5Cl_4$ , $C_5H_5NO_2$ , $C_3H_7OH$ , $C_5H_{11}OH$ , $PhCH_2OH$ , $Me_2CO$ (627)
$C_5H_{10}O_2$	Isobutyl formate (375 †)		Di- <i>n</i> -propylamine (52.3, 153.3)
$C_5H_{10}O_2$	<i>n</i> -Propyl acetate (592.2)	$C_6H_{15}N$	Triethylamine (101)
$C_5H_{10}O_2$	Ethyl propionate (592.2, 652)	$C_7H_5N$	Benzonitrile (101, 169 †)
$C_5H_{10}O_2$	Methyl butyrate (652)	$C_7H_5NS$	Phenylisothiocyanate (100, 101)
$C_5H_{10}O_2$	Methyl isobutyrate (652)	$C_7H_6O$	Benzaldehyde (100, † 101, 169, † 378, † 436)
$C_5H_{10}O_3$	Ethyl lactate (592.2)	$C_7H_6O_2$	Benzoic acid (595)
$C_5H_{10}O_3$	Ethyl carbonate (101, 592.2)	$C_7H_7Cl$	Benzyl chloride (1, † 169 †)
$C_5H_{11}Br$	Amyl bromide (1, † 169 †)	$C_7H_7NO$	<i>o</i> -( <i>p</i> -)Nitrotoluene (101)
$C_5H_{11}Cl$	Amyl chloride (169 †)	$C_7H_8$	Toluene (8, 46.5, † 100, 101, 152, 169, † 436, 437, 501, † 502, 555 †)
$C_5H_{11}I$	Amyl iodide (1, † 169 †)		Benzyl alcohol (374, † 627)
$C_5H_{11}N$	Piperidine (100, 101, 595)	$C_7H_8O$	Anisole (100, 101)
$C_5H_{11}NO_2$	Amyl nitrite (1 †)	$C_7H_9N$	Benzylamine (52.2, 153.3)



Formula	Name, solvents and literature	Formula	Name, solvents and literature
<b>Infra-red.—(Continued)</b>			
$C_7H_9N$	Methylaniline (51, 101, 153.3)	$C_9H_{18}O_2$	Isoamyl butyrate (652)
$C_7H_9N$	<i>o</i> -Toluidine (101)	$C_9H_{18}O_2$	Isoamyl isobutyrate (652)
$C_7H_9N$	<i>p</i> -Toluidine (153.3, 436)	$C_9H_{20}O$	Nonyl alcohol (377†)
$C_7H_{11}O_4$	Diethyl malonate (375,† 376,† 652)	$C_9H_{21}N$	Tri- <i>n</i> -propylamine (52.3, 153.3)
$C_7H_{11}O_4$	Dimethyl glutarate (375†)	$C_{10}H_7NO_2$	$\alpha$ -Nitronaphthalene (597)
$C_7H_{14}$	Dimethylcyclopentane (101†)	$C_{10}H_8$	Naphthalene (52, 101, 436); $CS_2$ , $CCl_4$ (597)
$C_7H_{14}$	Methylcyclohexane (437)	$C_{10}H_8O$	$\alpha(\beta)$ -Naphthol: $CCl_4$ , $CS_2$ (597)
$C_7H_{14}O$	Heptaldehyde (378†)	$C_{10}H_9N$	$\alpha(\beta)$ -Naphthylamine: $CCl_4$ , $CS_2$ (153.3, 597)
$C_7H_{14}O$	Dipropyl ketone (378†)	$C_{10}H_{10}O_2$	Safrole (101)
$C_7H_{14}O_2$	Amyl acetate (376,† 592.2)	$C_{10}H_{12}O$	Cumic aldehyde (101)
$C_7H_{14}O_2$	Isoamyl acetate (652)	$C_{10}H_{12}O$	Anethole (1,† 374,† 376†)
$C_7H_{16}$	Heptane (152, 153)	$C_{10}H_{12}O$	Isopropyl phenyl ketone (375,† 378†)
$C_7H_{16}O$	Heptyl alcohol (377†)	$C_{10}H_{12}O$	Propyl phenyl ketone (375†)
$C_7H_{16}O_2$	Butylglycerol (377†)	$C_{10}H_{12}O_2$	Eugenol (100,† 101)
$C_8H_6$	Phenylacetylene (374†)	$C_{10}H_{14}$	Cymene (101, 436)
$C_8H_8O$	Acetophenone (378†)	$C_{10}H_{14}$	Diethylbenzene (46.5†)
$C_8H_8O_2$	Anisaldehyde (374,† 378†)	$C_{10}H_{14}O$	Thymol (100,† 101)
$C_8H_8O_2$	Phenyl acetate (101)	$C_{10}H_{14}O$	Carvacrol (100,† 101); Vap. (340†)
$C_8H_8O_2$	Methyl benzoate (592.2)	$C_{10}H_{14}N_2$	Nicotine (595)
$C_8H_8O_2$	Methyl salicylate (1,† 100,† 101)	$C_{10}H_{16}N$	Butylaniline (51, 153.2)
$C_8H_{10}$	Ethylbenzene (46.5,† 436, 501†)	$C_{10}H_{16}N$	Diethylaniline (51)
$C_8H_{10}$	Xylene (169,† 555†)	$C_{10}H_{16}$	Limonene (100,† 101)
$C_8H_{10}$	<i>o</i> -Xylene (46.5,† 100, 101, 436, 437,† 501,† 502)	$C_{10}H_{16}$	Pinene (100,† 101)
$C_8H_{10}$	<i>m</i> -Xylene (46.5,† 101,† 153.2, 436, 437, 501†)	$C_{10}H_{18}O$	Eucalyptol (100,† 101)
$C_8H_{10}$	<i>p</i> -Xylene (46.5,† 100,† 101, 152, 436, 437,† 501†)	$C_{10}H_{18}O$	Terpineol (100,† 101)
$C_8H_{10}N_2O$	<i>p</i> -Nitrosodimethylaniline (101, 489)	$C_{10}H_{18}O_2$	Ethyl diethylacetoacetate (1†)
$C_8H_{10}O_2$	Dimethylresorcinol (376†)	$C_{10}H_{20}$	Decylene (73,† 101)
$C_8H_{11}N$	Dimethylaniline (1, 51, 101, 153.2)	$C_{10}H_{20}O$	Menthol (100,† 101)
$C_8H_{11}N$	Ethylaniline (51, 153.2)	$C_{10}H_{20}O$	Decyl aldehyde (378†)
$C_8H_{11}N$	Xylidine (100, 101)	$C_{10}H_{20}O_2$	Methylhexylcarbinyl acetate (652)
$C_8H_{11}N$	Methyl- <i>p</i> -toluidine (153.3)	$C_{10}H_{20}O_2$	Amyl valerate (376†)
$C_8H_{14}O_4$	Diethyl succinate (101, 376,† 652)	$C_{10}H_{20}O_2$	Isoamyl isovalerate (652)
$C_8H_{16}$	Dimethylcyclohexane (374,† 437)	$C_{10}H_{22}$	Decane (101)
$C_8H_{16}O$	Hexyl methyl ketone (378†)	$C_{10}H_{22}O$	Decyl alcohol (377†)
$C_8H_{16}O$	Octyl aldehyde (378†)	$C_{10}H_{22}O$	Amyl ether (1†)
$C_8H_{16}O_2$	Butyl butyrate (652)	$C_{10}H_{22}O_2$	$\alpha$ -Dimethyl- $\beta$ -hexylglycol (377†)
$C_8H_{16}O_2$	Isoamyl propionate (652)	$C_{10}H_{22}N$	Diisoamylamine (52.3, 153.3)
$C_8H_{17}N$	Coniine (595)	$C_{11}H_{11}N$	Methyl- $\alpha$ -naphthylamine (153.3)
$C_8H_{18}$	Octane (100, 101, 152)	$C_{11}H_{12}O$	Allylacetophenone (374,† 375†)
$C_8H_{18}O$	<i>n</i> -Octyl alcohol (376,† 377†)	$C_{11}H_{12}O_2$	Ethyl cinnamate (374,† 375†)
$C_8H_{18}O$	<i>sec</i> -Octyl alcohol (377†)	$C_{11}H_{12}O_2$	Ethyl benzoylacetate (376†)
$C_8H_{18}O$	Butyl ether (152)	$C_{11}H_{14}O$	Isobutyl phenyl ketone (378†)
$C_8H_{18}O$	Octyl alcohol (652)	$C_{11}H_{16}N_2O_2$	Pilocarpine (595)
$C_8H_{18}O_2$	$\alpha$ -Dimethyl- $\beta$ -isobutylglycol (377†)	$C_{11}H_{17}N$	Isoamylaniline (51, 153.2)
$C_8H_{19}N$	Di- <i>n</i> -butylamine (52.3)	$C_{11}H_{22}O$	Undecyl aldehyde (378†)
$C_8H_7N$	Quinoline (101, 595)	$C_{11}H_{24}O$	Undecyl alcohol (377†)
$C_8H_{10}O$	Ethyl phenyl ketone (378†)	$C_{11}H_{24}O_2$	$\alpha$ -Methyl- $\alpha$ -ethyl- $\beta$ -hexylglycol (377†)
$C_8H_{10}O_2$	Ethyl benzoate (1†)	$C_{12}H_{10}$	Diphenyl: $CCl_4$ , $C_6H_6$ (101)
$C_8H_{12}$	Cumene (101)	$C_{12}H_{10}N_2$	Azobenzene (101)
$C_8H_{12}$	Mesitylene (46.5,† 100,† 101, 152, 153, 436, 437†)	$C_{12}H_{10}O_2$	Ethyl salicylate (592.2)
$C_8H_{12}$	Propylbenzene (374†)	$C_{12}H_{11}N$	Diphenylamine: P (52.1, 153.3)
$C_8H_{12}O$	Phenylpropyl alcohol (1†)	$C_{12}H_{12}N$	Dimethyl- $\alpha$ -naphthylamine (153.3)
$C_8H_{12}O$	Benzyl ethyl ether (1†)	$C_{12}H_{12}N$	Ethyl- $\alpha$ -naphthylamine (153.3)
$C_8H_{12}N$	Methylethylaniline (51, 153.2)	$C_{12}H_{14}O_2$	Eugenyl acetate (101)
$C_8H_{12}N$	Propylaniline (51, 153.2)	$C_{12}H_{14}O_4$	Diethyl phthalate (592.2)
$C_8H_{12}N$	Dimethyl- <i>p</i> -toluidine (153.3)	$C_{12}H_{16}N$	Dipropylaniline (51, 153.2)
$C_8H_{14}$	Cyclohexylpropine (374†)	$C_{12}H_{22}O_4$	Dibutyl tartrate (375†)
$C_8H_{14}O_6$	Triacetin (374)	$C_{12}H_{22}O_{11}$	Saccharose (102)
$C_8H_{16}ClNO_2$	Ecgonine hydrochloride (595)	$C_{12}H_{22}O_{11}$	Lactose (102)
$C_8H_{16}O_2$	Amyl crotonate (374,† 376†)	$C_{12}H_{22}O_{11}$	Maltose (102)
$C_8H_{16}O_4$	Diethyl glutarate (376†)	$C_{12}H_{24}$	Dodecylene (73,† 101)
$C_8H_{16}O_4$	Dimethyl $\beta$ -methyladipate (375†)	$C_{12}H_{26}$	Dodecane (101)
$C_8H_{18}O$	Nonyl aldehyde (378)	$C_{12}H_{26}O$	Dodecyl alcohol (377†)
		$C_{12}H_{26}O_2$	$\alpha$ -Methyl- $\alpha$ -propyl- $\beta$ -hexylglycol (377†)



Formula	Name, solvents and literature
<b>Infra-red.—(Continued)</b>	
$C_{12}H_{27}N$	Tri- <i>n</i> -butylamine (52.3)
$C_{13}H_{27}Cl$	Chlorotridecane (101)
$C_{14}H_{19}N$	Dibenzylamine (52.2, 153.3)
$C_{14}H_{17}N$	Diethyl- $\alpha$ -naphthylamine (153.3)
$C_{14}H_{23}N$	Dibutylaniline (51, 153.2)
$C_{14}H_{26}O_6$	Diamyl tartrate (375†)
$C_{14}H_{29}Cl$	Chlorotetradecane (101†)
$C_{15}H_{21}NO_2$	$\beta$ -Eucaine (595)
$C_{15}H_{21}N_3O_2$	Eserine (595)
$C_{15}H_{28}O_4$	Diethyl dibutylmalonate (375†)
$C_{16}H_{30}$	Pentadecylene (73,† 101)
$C_{16}H_{33}N$	Triisoamylamine (52.3, 153.3)
$C_{16}H_{16}O$	1-Phenyl-2-benzoylpropane (378)
$C_{16}H_{21}NO_3$	Homoatropine (595)
$C_{16}H_{32}$	Hexadecylene (73,† 101)
$C_{16}H_{34}$	Hexadecane (101)
$C_{17}H_{19}NO_3$	Piperine (595)
$C_{17}H_{22}ClNO_4$	Cocaine hydrochloride (595)
$C_{17}H_{23}NO_3$	Atropine (595)
$C_{17}H_{35}Cl$	Chloroheptadecane (101)
$C_{18}H_{15}N$	Triphenylamine: P (52.1, 153.3)
$C_{18}H_{20}O_2$	Ethyl dibenzylacetate (1†)
$C_{18}H_{21}NO_3$	Codeine (595)
$C_{18}H_{32}O_{16}$	Raffinose (102)
$C_{18}H_{34}O_2$	Oleic acid (101, 104, 105)
$C_{18}H_{36}$	Octadecylene (101)
$C_{18}H_{36}O_2$	Stearic acid (101)
$C_{18}H_{38}$	Octadecane (101)
$C_{19}H_{22}N_2O$	Cinchonidine (595)
$C_{19}H_{36}$	Hydrocarbons (101)
$C_{20}H_{24}N_2O_2$	Quinidine (595)
$C_{20}H_{24}N_2O_2$	Quinine (595)
$C_{21}H_{21}N$	Tribenzylamine (52.2, 153.3)
$C_{22}H_{23}NO_7$	Narcotine (595)
$C_{22}H_{42}$	Hydrocarbons (101)
$C_{23}H_{26}N_2O_4$	Brucine (102, 595)
$C_{23}H_{46}$	Tricosylene (101)
$C_{23}H_{48}$	Tricosane (101)
$C_{24}H_{48}$	Tetracosylene (101)
$C_{24}H_{50}$	Tetracosane (100, 101)
$C_{26}H_{52}O_2$	Cerotic acid (101†)
$C_{30}H_{62}O$	Myricyl alcohol (100, 101)
$C_{34}H_{47}NO_{11}$	Aconitine (595)
$C_{40}H_{50}N_4O_8S$	Quinine sulfate (595)

## Organic Compounds of Mixed or Unknown Composition

Alcohols ( $C_nH_{2n+1}OH$ ) (374†).  
 $\alpha$ -Alcohols ( $R.CH:CHOH$ ) (374†).  
 $\beta$ -Alcohols ( $R.CH:CHCH_2OH$ ) (374†).  
Asphaltum (mixed hydrocarbons) (101, 103, 417).  
Bakelite (105).  
Belladonna ( $C_{17}H_{21}NO_4$  and  $C_{17}H_{23}NO_3$ ) (595).  
Boxwood oil (399).  
Bromocarbinols ( $CH_2BrCHBr.CHOHR$ ) (374†).  
Castor oil (653).  
Catfish oil (105).  
Celluloid (399, 653†).  
Cottonseed oil (105, 152, 153, 186).  
Fatty acid esters (374†).  
Gelatin (104).  
Illuminating gas: Vap. (101).  
Juniper oil (148).

Kerosene (153); cf. Vol. II, p. 153.  
Ketones (374†).  
Lard oil (105, 153).  
Lavender oil (148†).  
Linseed oil (104).  
Linseed oil fatty acids (105).  
Nitrocellulose (celluloids, pyralin) (103, 105).  
Ohio oils (101).  
Olive oil (1,† 104, 105, 148,† 555†).  
Paraffin oil (105, 169,† 555,† 558†); cf. Vol. II, p. 153.  
Peanut oil (105).  
Petroleum (101, 153, 555†); cf. Vol. II, p. 153.  
Poplar oils (399).  
Resin (101).  
Rubber (102, 555,† 558,† 653†).  
Rosemary oil (148†).  
Salicylic acid esters ( $HOC_6H_4COOR$ ) (374).  
Sassafras oil (148†).  
Silk, oiled (555†).  
Soya bean oil (105).  
Tung oil (105).  
Turpentine (1,† 101, 148†).  
Vinyl carbinols ( $CH_2:CH.CHOHR$ ) (374†).

Formula	Name, solvents and literature
<b>Ultra-violet and Visible</b>	
$CBrN_3O_6$	Bromonitroform: EtOH (198)
$CBr_2N_2O_4$	Dibromodinitromethane: EtOH (198)
$CBr_4$	Carbon tetrabromide (440†)
$CClN_3O_6$	Chloronitroform: EtOH (198)
$CCl_2O$	Carbonyl chloride: Liq., Vap. (83†)
$CCl_2S$	Thiocarbonyl chloride: EtOH (536†)
$CCl_4$	Carbon tetrachloride (261,† 440†)
$Cl_4$	Carbon tetraiodide: EtOH (442†)
$CN_4O_8$	Tetranitromethane: EtOH (259, 421, 664); EtOH and other solvents (259, 421); $CHCl_3$ (421)
$CS_2$	Carbon disulfide: Liq., Vap. (486)
$CHBrN_2O_4$	Bromodinitromethane: $H_2O$ (259, 291); $HCl$ (259, 291); $Et_2O$ (291); K salts: $H_2O$ (198, 291)
$CHBr_3$	Bromoform (440†)
$CHCl_3$	Chloroform (261,† 440†)
$CHI_3$	Iodoform: EtOH (116, 386, 442,† 493,† 573†); $CCl_4$ (493,† 573†); $C_6H_6$ (493†); hexane (573†)
$CHN$	Hydrocyanic acid (262†)
$CHNO$	Cyanic acid, K salt: $H_2O$ (280†)
$CHNS$	Thiocyanic acid, Co salt (227); $Et_2O$ (320); Hg salt: EtOH (113)
$CHN_3O_6$	Nitroform (228); $H_2O$ (291); $H_2SO_4$ (198, 255); EtOH (259); $Et_2O$ (291); Ag salt: $H_2O$ , $Et_2O$ (255); Hg salt: $H_2O$ , $CHCl_3$ , EtOH (255); K salt: $H_2O$ (198, 255, 291); Na salt: EtOH (244†)
$CH_2Br_2$	Methylene bromide (440†)
$CH_2Cl_2$	Methylene chloride (440†)
$CH_2I_2$	Methylene iodide: EtOH (116, 442†)
$CH_2N_2O_4$	Dinitromethane (228); $Et_2O$ (291); $H_2O$ (255, 291); $H_2SO_4$ , NaOH (255); Na salts: EtOH (244); K salt: $H_2O$ (291)
$CH_2N_2O_6S_2$	Diazomethanedisulfonic acid, K salt: KOH (247)



Formula	Name, solvents and literature	Formula	Name, solvents and literature
<b>Ultra-violet and Visible.—(Continued)</b>			
CH <sub>2</sub> O	Formaldehyde (54, 83); Vap. (83, 538); EtOH (534†); cf. p. 359	C <sub>2</sub> H <sub>3</sub> NO	Methyl isocyanate: P (280†)
CH <sub>2</sub> O <sub>2</sub>	Formic acid (54, † 56, † 57, † 60, † 182, † 240, 298†); P (252); H <sub>2</sub> O (240, 252, 659, † 660); EtOH (240, 252); Ba, Ca, K, Li, Mg, Sr salts: H <sub>2</sub> O = ? (660); Co salt: H <sub>2</sub> O (320); Na salt: H <sub>2</sub> O (182, 659, † 660); NH <sub>4</sub> salt: H <sub>2</sub> O (240, 660)	C <sub>2</sub> H <sub>3</sub> NO <sub>2</sub>	Isonitrosoacetic acid: EtOH, EtOH + alk. (31)
CH <sub>2</sub> S <sub>2</sub>	Trithiocarbonic acid: CHCl <sub>3</sub> , C <sub>6</sub> H <sub>5</sub> CH <sub>3</sub> , ligroin (212†); Ba salt: H <sub>2</sub> O (212†)	C <sub>2</sub> H <sub>3</sub> NO <sub>4</sub>	Nitroacetic acid: EtOH, Et <sub>2</sub> O (255); K salt: H <sub>2</sub> O (255)
CH <sub>2</sub> S <sub>4</sub>	Perthiocarbonic acid: CHCl <sub>3</sub> , C <sub>6</sub> H <sub>5</sub> CH <sub>3</sub> , ligroin (212†); Na salt: H <sub>2</sub> O (212†)	C <sub>2</sub> H <sub>4</sub>	Ethylene: Vap. (261, † 601, 602)
CH <sub>3</sub> I	Methyl iodide (442†); EtOH (116)	C <sub>2</sub> H <sub>4</sub> Cl <sub>2</sub>	Ethylene chloride (261†)
CH <sub>3</sub> NO <sub>2</sub>	Nitromethane (655†); H <sub>2</sub> O (291, 664); EtOH (25, 255, 664); H <sub>2</sub> SO <sub>4</sub> (255); alk. (25, 255, 664); Vap. (540); Na salt: H <sub>2</sub> O (291); EtOH (244)	C <sub>2</sub> H <sub>4</sub> I <sub>2</sub>	Ethylene iodide: EtOH (116, 423)
CH <sub>3</sub> N <sub>2</sub> O	Nitrourea: EtOH + alk. (25)	C <sub>2</sub> H <sub>4</sub> NO <sub>2</sub>	Nitroacetaldoxime (255†)
CH <sub>4</sub>	Methane (192†)	C <sub>2</sub> H <sub>4</sub> N <sub>2</sub> O <sub>2</sub>	Ethyl nitrolic acid: MeOH (245); K salt: MeOH (245); iso-K salt: MeOH (245)
CH <sub>4</sub> N <sub>2</sub>	Hydrazomethane (247)	C <sub>2</sub> H <sub>4</sub> N <sub>2</sub> O <sub>4</sub>	Methazonic acid: Et <sub>2</sub> O, H <sub>2</sub> O, NaOH (255)
CH <sub>4</sub> N <sub>2</sub> O	Urea (25, 594); cf. p. 359	C <sub>2</sub> H <sub>4</sub> N <sub>4</sub>	Dinitroethane and K salt: H <sub>2</sub> O (291)
CH <sub>4</sub> N <sub>2</sub> O <sub>2</sub>	Methylnitroamine and salts; EtOH (25); Co salt: H <sub>2</sub> O (162); Cu salt: H <sub>2</sub> O (163); Ni salt: H <sub>2</sub> O (163, 164)	C <sub>2</sub> H <sub>4</sub> N <sub>4</sub> O <sub>2</sub>	Tetrazine: Vap. (386)
CH <sub>4</sub> N <sub>2</sub> S	Thiourea (424); cf. p. 359	C <sub>2</sub> H <sub>4</sub> O	Azodicarbonamide (247)
CH <sub>4</sub> N <sub>2</sub> S	Ammonium thiocyanate (424)	C <sub>2</sub> H <sub>4</sub> OS	Acetaldehyde (54, † 56, † 59, † 65, † 176.2† 309, † 310, † 538, † 571); hexane (419†); EtOH, Vap. (538); v. p. 359
CH <sub>4</sub> N <sub>2</sub> O <sub>2</sub>	Nitroguanidine: EtOH + alk. (25)	C <sub>2</sub> H <sub>4</sub> O <sub>2</sub>	Thioacetic acid and K salt (252)
CH <sub>4</sub> O	Methyl alcohol (54, 56, 286, † 438†)		Acetic acid (54, † 55, † 56, † 57, † 58, † 59, † 60, † 64, † 66, † 67, † 298, † 382†); H <sub>2</sub> O (65, 182, † 204, † 231, 240, 252); P (240, 252); EtOH (231, 240, 252); Et <sub>2</sub> O, hexane (240); MeOH, C <sub>6</sub> H <sub>11</sub> -OH (252); ligroin (231, 252); cf. p. 359; Ba salt: H <sub>2</sub> O (231, 660†); Ca salt: H <sub>2</sub> O (660†); Co salt (331, † 388); Cu salt (331, † 382); Hg salt (96); H <sub>2</sub> O (113); K salt: H <sub>2</sub> O (231, 240, 252, 660†); Li, Mg salt: H <sub>2</sub> O (660†); NH <sub>4</sub> salt: H <sub>2</sub> O (231, 240, 660†); Ni salt: H <sub>2</sub> O (331†); Na salt: (182†); H <sub>2</sub> O (240, 659, † 660†); Pb salt: H <sub>2</sub> O (272); Sr, Zn salt: H <sub>2</sub> O (660†)
CH <sub>4</sub> O <sub>2</sub> S	Methylsulfonic acid, Na salt (567)	C <sub>2</sub> H <sub>4</sub> O <sub>2</sub>	Methyl formate (55, † 57, † 60, † 240, 252)
CH <sub>4</sub> N	Methylamine (63)	C <sub>2</sub> H <sub>4</sub> O <sub>2</sub>	Glycollic aldehyde: H <sub>2</sub> O, EtOH (425†)
CH <sub>4</sub> CIN	Methylamine hydrochloride: H <sub>2</sub> O (276†)	C <sub>2</sub> H <sub>5</sub> Cl	Ethyl chloride (261†)
CH <sub>4</sub> CIN <sub>2</sub>	Guanidine hydrochloride: cf. p. 359	C <sub>2</sub> H <sub>5</sub> ClO	Ethylene chlorohydrin (592.3); P, C <sub>6</sub> H <sub>6</sub> , Vap. (372.2†)
C <sub>2</sub> Cl <sub>4</sub>	Tetrachloroethylene: EtOH (441†)	C <sub>2</sub> H <sub>5</sub> ClO	Ethyl hypochlorite: ligroin (562, 568)
C <sub>2</sub> Cl <sub>6</sub>	Hexachloroethane: EtOH (441†)	C <sub>2</sub> H <sub>5</sub> I	Ethyl iodide: EtOH (116, 386, 573†); C <sub>6</sub> H <sub>6</sub> (386); H <sub>2</sub> O, hexane, CCl <sub>4</sub> (573†)
C <sub>2</sub> I <sub>2</sub>	Diiodoacetylene (423†)	C <sub>2</sub> H <sub>5</sub> NO	Acetaldoxime (63†); H <sub>2</sub> O (276†)
C <sub>2</sub> HCl <sub>3</sub> O	Chloral: Et <sub>2</sub> O, Vap. (538); cf. p. 359	C <sub>2</sub> H <sub>5</sub> NO	Acetamide (63†); cf. p. 359
C <sub>2</sub> HCl <sub>3</sub> O <sub>2</sub>	Trichloroacetic acid (182†); H <sub>2</sub> O (182, † 231, 240, 659†); EtOH, Et <sub>2</sub> O (240); ligroin (231, 240); HCl, H <sub>2</sub> SO <sub>4</sub> (231); NH <sub>4</sub> salt: H <sub>2</sub> O, EtOH (240); Na salt: H <sub>2</sub> O (182, † 659)	C <sub>2</sub> H <sub>5</sub> NO <sub>2</sub>	Aminoacetic acid: v. p. 359; Co salt (397†); H <sub>2</sub> O (396); Cu salt (382†); H <sub>2</sub> O (391)
C <sub>2</sub> H <sub>2</sub>	Acetylene (261, † 303, 600, 601); EtOH, Me <sub>2</sub> CO (441†)	C <sub>2</sub> H <sub>5</sub> NO <sub>2</sub>	Nitroethane (228); EtOH (25, 255, 664); alk. (255, 664)
C <sub>2</sub> H <sub>2</sub> Br <sub>2</sub>	Dibromoethylene, <i>cis</i> and <i>trans</i> : v. p. 359	C <sub>2</sub> H <sub>5</sub> NO <sub>2</sub>	Ethyl nitrite: EtOH, EtOH + EtSH (259)
C <sub>2</sub> H <sub>2</sub> Cl <sub>2</sub>	Dichloroethylene, <i>cis</i> and <i>trans</i> : EtOH, hexane (154†); cf. p. 359	C <sub>2</sub> H <sub>5</sub> NO <sub>2</sub>	Ethyl nitrate: EtOH (240, 562); ligroin (566)
C <sub>2</sub> H <sub>2</sub> Cl <sub>4</sub>	<i>sym.</i> -Tetrachloroethane: EtOH (441†)	C <sub>2</sub> H <sub>5</sub> NO <sub>2</sub>	Triazoethane: v. p. 359
C <sub>2</sub> H <sub>2</sub> I <sub>2</sub>	Diiodoethylene (423†); cf. p. 359	C <sub>2</sub> H <sub>5</sub> NO <sub>2</sub>	Biuret (594)
C <sub>2</sub> H <sub>2</sub> N <sub>2</sub> O <sub>4</sub>	Azodicarboxylic acid; K salt: KOH (247)	C <sub>2</sub> H <sub>5</sub> N <sub>2</sub>	Azomethane (247): Vap. (540.5)
C <sub>2</sub> H <sub>2</sub> O	Ketene: hexane (370, † 371†); cf. p. 359	C <sub>2</sub> H <sub>5</sub> N <sub>2</sub> O	Dimethylnitrosoamine: EtOH (25)
C <sub>2</sub> H <sub>2</sub> O <sub>2</sub>	Glyoxal: EtOH (538); hexane (418, † 419†); Vap. (418, 538); cf. p. 359	C <sub>2</sub> H <sub>5</sub> N <sub>2</sub> O <sub>2</sub>	Ethyl nitroamine, Co derivative (162); Cu salt (163); Ni salt (164)
C <sub>2</sub> H <sub>2</sub> O <sub>4</sub>	Oxalic acid (54, 56, † 58, † 66, † 428, † 645.5†); H <sub>2</sub> O (252, 659, † 660†); EtOH (252); cf. p. 359; Co salt: H <sub>2</sub> O (320); K salt: H <sub>2</sub> O (252, 659†); Na salt: H <sub>2</sub> O (660†)	C <sub>2</sub> H <sub>5</sub> N <sub>2</sub> O <sub>2</sub>	Ethyl nitrosohydroxylamine, Cu salt: H <sub>2</sub> O (163)
C <sub>2</sub> H <sub>3</sub> ClO	Acetyl chloride: hexane (252)	C <sub>2</sub> H <sub>5</sub> O	Ethyl alcohol (54, † 56, † 298, † 438†)
C <sub>2</sub> H <sub>3</sub> ClO <sub>2</sub>	Chloroacetic acid: (182†); HCl (240); H <sub>2</sub> O (231, 659†); EtOH (231, 240); K, NH <sub>4</sub> salts: H <sub>2</sub> O (240); Metallic salts: H <sub>2</sub> O (231); Na salt: H <sub>2</sub> O (182, † 659†)	C <sub>2</sub> H <sub>5</sub> O <sub>2</sub> S	Ethylsulfonic acid, K salt (567)
C <sub>2</sub> H <sub>3</sub> Cl <sub>2</sub> O <sub>2</sub>	Chloral hydrate: EtOH (538); cf. p. 359	C <sub>2</sub> H <sub>5</sub> S	Dimethyl sulfide: EtOH (242)
C <sub>2</sub> H <sub>3</sub> N	Methyl isocyanide (63†)	C <sub>2</sub> H <sub>7</sub> N	Ethylamine (63†)
C <sub>2</sub> H <sub>3</sub> N	Acetonitrile (63†)	C <sub>2</sub> H <sub>7</sub> N	Dimethylamine (63†)
		C <sub>2</sub> H <sub>7</sub> NO	Colamine: v. p. 359
		C <sub>2</sub> H <sub>5</sub> N <sub>2</sub>	Ethylenediamine (63†); (+HCl) cf. p. 359



Formula	Name, solvents and literature	Formula	Name, solvents and literature
Ultra-violet and Visible.—(Continued)			
$C_3Cl_3N_3$	Cyanuric chloride: EtOH (280†)	$C_3H_7NO_2$	Urethane: EtOH + NaOEt (82)
$C_3HBr_5O$	Pentabromoacetone (176)	$C_3H_7NO_2$	$\alpha$ -Alanine (594); EtOH (650†); cf. p. 359; Co salt (397†); Cu salt (382†); H <sub>2</sub> O (391); $\beta$ -Alanine, Cu salt: EtOH (391)
$C_3H_2N_2O_3$	Parabanic acid: v. p. 359	$C_3H_7NO_2$	1(2)-Nitropropane: EtOH, EtOH + MeONa (664)
$C_3H_3NO_6$	Nitromalonic acid, salts: H <sub>2</sub> O (255)	$C_3H_7NO_2$	Dimethyl thiosulfocarbamate, Co salt: CHCl <sub>3</sub> (123)
$C_3H_3NS$	Thiazole (554)	$C_3H_7NO_2$	Glyceryl $\alpha(\beta)$ -mononitrate: H <sub>2</sub> O (311)
$C_3H_3N_3O_3$	Cyanuric acid: H <sub>2</sub> O (262, 280); cf. p. 359	$C_3H_7NO_2$	Serine (265,† 594†)
$C_3H_3N_3O_3$	Nitrocyanacetamide: H <sub>2</sub> SO <sub>4</sub> , Et <sub>2</sub> O (258); Na salt: H <sub>2</sub> O (258)	$C_3H_8N_2O_2$	$\alpha(\beta)$ -Diaminopropionic acid (391†)
$C_3H_4Br_2N_2O_2$	Dibromomalonamide: H <sub>2</sub> O (198)	$C_3H_8N_2O_2$	Propylnitroamine: H <sub>2</sub> O (162)
$C_3H_4Cl_2O$	Dichloroacetone (176)	$C_3H_8O$	Propyl alcohol (54,† 56,† 58,† 438†)
$C_3H_4N_2$	Pyrazole (554)	$C_3H_8O$	Isopropyl alcohol (261†)
$C_3H_4N_2$	Glyoxaline (554)	$C_3H_8O_2$	Methylal (534†)
$C_3H_4N_2O_4$	Oxaluric acid (594); cf. p. 359	$C_3H_8N$	Propylamine (63†)
$C_3H_4O$	Acrolein (59,† 539); H <sub>2</sub> O, hexane, Et <sub>2</sub> O (418†); Vap. (418, 539); cf. p. 359	$C_3H_8N$	Trimethylamine (63†); EtOH (286)
$C_3H_4O_2$	Acrylic acid: hexane (418†); cf. p. 359	$C_4HBr_2NO_2$	Dibromomaleinimide: EtOH (389)
$C_3H_4O_2$	Methylglyoxal: v. p. 359	$C_4H_2BrNO_2$	Bromomaleinimide: EtOH (389)
$C_3H_4O_3$	Pyruvic acid (62,† 66,† 68†); cf. p. 359	$C_4H_2O_3$	Maleic acid anhydride (171†); AcOH, H <sub>2</sub> SO <sub>4</sub> (500); cf. p. 359
$C_3H_4O_4$	Malonic acid (54,† 56,† 58†); H <sub>2</sub> O (659,† 660†); Na salt: NaOH (82); H <sub>2</sub> O (659,† 660†)	$C_4H_2O_4$	Acetylenedicarboxylic acid (423)
$C_3H_5Br$	Allyl bromide: EtOH, Vap. (539)	$C_4H_3ClN_2O_2$	Aminochloromaleinimide: EtOH (389)
$C_3H_5BrN_2O_2$	Bromomalonamide: H <sub>2</sub> O (198)	$C_4H_3N_2O_4$	Violuric acid: H <sub>2</sub> O, EtOH (269†); Na salt: H <sub>2</sub> O (269†); cf. p. 359
$C_3H_5ClO$	Chloroacetone (176); EtOH, Vap. (538)	$C_4H_3N_2O_5$	Nitrobarbituric acid (228); H <sub>2</sub> O, H <sub>2</sub> SO <sub>4</sub> , NaOH (255)
$C_3H_5NO$	Ethyl isocyanate: P (280†); hexane (370,† 371†)	$C_4H_4BrNO_2$	Succinbromoimide: EtOH (199)
$C_3H_5NO_2$	Isonitrosoacetone (176); EtOH, alk. (31)	$C_4H_4ClNO_2$	Succinchloroimide: EtOH (199)
$C_3H_5N_3O_3$	Nitroglycerol: H <sub>2</sub> O (311)	$C_4H_4N_2O_3$	Barbituric acid (129†); H <sub>2</sub> O (269†); cf. p. 359
$C_3H_6N_2$	Pyrazoline (554)	$C_4H_4N_2O_5$	Alloxan (129†); H <sub>2</sub> O (269†); K salt: EtOH (269†)
$C_3H_6N_2O_2$	Malonamide: H <sub>2</sub> O, NaOH (82, 198)	$C_4H_4O$	Furan: EtOH (273,† 511†); Vap. (511); cf. p. 359
$C_3H_6N_2O_3$	Urethanediazohydroxide, Na salt: H <sub>2</sub> O (247)	$C_4H_4O_2$	Methyl propiolate (58†)
$C_3H_6N_2O_3$	Nitrosourethane: EtOH (25)	$C_4H_4O_2$	Diketocyclobutane: hexane, Et <sub>2</sub> O (370,† 371†)
$C_3H_6N_2O_4$	Nitrourethane: EtOH, alk. (25)	$C_4H_4O_4$	Fumaric acid (64,† 423); H <sub>2</sub> O (659†); EtOH (237, 429,† 430,† 607); Na salt: H <sub>2</sub> O (659†)
$C_3H_6N_2O_7$	Glyceryl $\alpha$ - $\beta$ ( $\gamma$ )-dinitrate: H <sub>2</sub> O (311)	$C_4H_4O_4$	Maleic acid (58,† 64,† 423, 607); EtOH (429,† 430†); Et <sub>2</sub> O (237); cf. p. 359
$C_3H_6N_6$	Melamine: H <sub>2</sub> O (280)	$C_4H_4O_6$	Oxalacetic acid and salts: H <sub>2</sub> O, HCl, EtOH, Et <sub>2</sub> O (237)
$C_3H_6O$	Allyl alcohol: hexane (58,† 418); P (261†); EtOH (428, 539); Vap. (418, 539); cf. p. 359	$C_4H_4O_6$	Hydroxyfumaric acid: Et <sub>2</sub> O (237)
$C_3H_6OS_2$	Xanthic acid: ligroin (211,† 252); EtOH (211,† 252); Et <sub>2</sub> O (211†); K salt: H <sub>2</sub> O (252)	$C_4H_4O_8$	Dihydroxyfumaric acid: EtOH (237)
$C_3H_6O$	Acetone (54,† 56,† 59,† 61,† 62,† 65,† 66,† 67,† 69,† 98, 175, 176, 191,† 228, 294, 308,† 309,† 310,† 410, 534, 545,† 574, 598,† 601); H <sub>2</sub> O (82, 204,† 497,† 609); EtOH (82, 220, 404, 497,† 538, 546,† 609); NaOH, HCl (82); vari- ous sol. (546,† 573†); Vap. (538†); cf. p. 359	$C_4H_4S$	Thiophene: P (486,† 511†); EtOH (273,† 511†); Vap. (486,† 511†); cf. p. 359
$C_3H_6O$	Propionaldehyde (54,† 56,† 59†); EtOH, Vap. (538); cf. p. 359	$C_4H_5ClN_2$	3-Methyl-5-chloropyrazole (554)
$C_3H_6O_2$	Ethyl formate (55,† 57,† 60†); P, ligroin, Et <sub>2</sub> O, EtOH (252)	$C_4H_5ClO_2$	$\beta$ -Chlorocrotonic acid (84,† 424); H <sub>2</sub> O (252); $\beta$ -Chloroisocrotonic acid (84,† 424)
$C_3H_6O_2$	Methyl acetate (54,† 56,† 57,† 60†); H <sub>2</sub> O, EtOH, Et <sub>2</sub> O, hexane (240)	$C_4H_5Cl_3O_2$	Ethyl trichloroacetate: EtOH, Et <sub>2</sub> O (240); lig- roin (231, 240)
$C_3H_6O_3$	Propionic acid (54,† 55,† 56,† 57,† 58,† 60,† 252); H <sub>2</sub> O (659,† 660†); cf. p. 359; Ba, Ca, K, Li, Mg, Na, NH <sub>4</sub> , Sr salts: H <sub>2</sub> O (659,† 660†)	$C_4H_5N$	Vinylacetonitrile (84†)
$C_3H_6O_3S$	Monoethylthiocarbonic acid (252)	$C_4H_5N$	Trimethylene carboxylic nitrile (84†)
$C_3H_6O_3$	Lactic acid (58†); CHCl <sub>3</sub> (134); cf. p. 359	$C_4H_5N$	Pyrrole: P, Vap. (511); EtOH (273,† 361, 362, 511); hexane (171†); cf. p. 359
$C_3H_6S_3$	Ethyl trithiocarbonate: ligroin, Et <sub>2</sub> O (212†); K salt: H <sub>2</sub> O (212†)	$C_4H_5NO_2$	Crotononitrile (84†)
$C_3H_6S_3$	Trithioformaldehyde (534†)	$C_4H_5NO_2$	Isocrotononitrile (84†)
$C_3H_7NO$	Propionamide (63†); EtOH (390); cf. p. 359; Hg salt (390)	$C_4H_5NO_2$	Methylacrylonitrile (84†)
$C_3H_7NO$	Acetoxime (63,† 276†); cf. p. 359	$C_4H_6N_2O$	Succinimide (199); H <sub>2</sub> O (389); EtOH (390); Mg salt: H <sub>2</sub> O (389); Hg salt (390)
		$C_4H_6N_2O$	Dimethylglyoxime anhydride (1.5)
		$C_4H_6N_2O_2$	3-Methyl-5-pyrazolone (554)
		$C_4H_6N_4O_3$	Ethyl diazoacetate: EtOH (247)
			Allantoin (594†); cf. p. 359



Formula	Name, solvents and literature	Formula	Name, solvents and literature
<b>Ultra-violet and Visible.—(Continued)</b>			
$C_4H_6O$	Crotonaldehyde: EtOH (539); Vap. (392, 539); hexane (392†); cf. p. 359	$C_4H_{10}O_2S$	Diethyl sulfite ( <i>sym.</i> and <i>unsym.</i> ) (567, 661); P (562)
$C_4H_6O_2$	Vinylacetic acid (84†)	$C_4H_{10}O_4S$	Diethyl sulfate: P (562)
$C_4H_6O_2$	Trimethylenecarbonic acid (84†)	$C_4H_{11}N$	Diethylamine (63†)
$C_4H_6O_2$	Diacetyl (36, 59, † 62, † 66, † 69, † 175, 176, 294, 410); hexane (369, † 370†); Vap. (370, † 538); cf. p. 359	$C_4H_{14}Cl_2N_2$	Tetramethylenediamine (putresceine) hydrochloride: <i>v.</i> p. 359
$C_4H_6O_2$	Crotonic acid (58, † 59, † 64, † 66, † 84†); $H_2O$ (252, 497†); EtOH (539, 607); Vap. (539); cf. p. 359	$C_5Cl_6N$	Pentachloropyridine (14); Vap. (520)
$C_4H_6O_2$	Isocrotonic acid (84†)	$C_5HCl_4N$	2, 3, 4, 5-Tetrachloropyridine (14); Vap. (520)
$C_4H_6O_3$	Acetic anhydride: $Et_2O$ (252)	$C_5H_2Cl_3N$	2, 3, 5-Trichloropyridine: Vap. (520)
$C_4H_6O_4$	Dimethyl oxalate: P, MeOH, EtOH, ligroin (120, 252)	$C_5H_2Cl_3N$	3, 4, 5-Trichloropyridine (14, 505†); Vap. (520)
$C_4H_6O_4$	Succinic acid (54, † 56, † 58, † 64, † 66†); $H_2O$ (659, † 660†); EtOH (120, 423, 607); cf. p. 359; Na salt: $H_2O$ (659, † 660†)	$C_5H_2Cl_4$	Tetrachlorocyclopentadiene (410)
$C_4H_6O_6$	Malic acid (58†)	$C_5H_2Cl_4N_2$	Tetrachloro-2-aminopyridine: Vap. (520)
$C_4H_6O_6$	<i>d</i> ( <i>l</i> )-Tartaric acid (58†); $H_2O$ (429, † 608, 660†); Co salt: $H_2O$ (320); Na salt: $H_2O$ (660†)	$C_5H_3Cl_2N$	3, 5-Dichloropyridine (504); Vap. (520)
$C_4H_6O_6$	<i>dl</i> -Tartaric acid (58†); $H_2O$ (608)	$C_5H_4N_4O$	6-Hydroxypurine (594†); $H_2O$ (127†)
$C_4H_6O_6$	Mesotartaric acid (608)	$C_5H_4N_4O_2$	2,6-Dihydroxypurine (594†), $H_2O$ (127†)
$C_4H_7ClO_2$	Ethyl chloroacetate: P (240); EtOH (231, 240)	$C_5H_4N_4O_2$	Uric acid (122, † 594†); $H_2O$ (127, † 269†); cf. p. 359; Li salt: $H_2O$ (269†)
$C_4H_7NO$	$\beta$ -Hydroxybutyronitrile (84†)	$C_5H_4O_2$	$\gamma$ -Pyrone: EtOH, EtOH + NaOEt (21)
$C_4H_7NO_2$	Diacetylmonoxime (1.5)	$C_5H_4O_2$	Furfuraldehyde: P, Vap. (511); $H_2O$ (180); EtOH (180, 273, † 511); cf. p. 359
$C_4H_7NO_2$	Isonitrosomethylacetone: EtOH, alk. (31)	$C_5H_4O_3$	Pyromeconic acid: EtOH, EtOH + NaOEt (21)
$C_4H_7NO_3$	Acetyl glycine: <i>v.</i> p. 359	$C_5H_4O_3$	Pyromucic acid (Furan- $\alpha$ -carboxylic acid): EtOH (273†); cf. p. 359
$C_4H_7NO_4$	Aspartic acid: <i>v.</i> p. 359	$C_5H_6N$	Pyridine (14, 38, † 428); P (486, 508); $H_2O$ (33, † 39†); EtOH (223, 263, † 312, † 486, 606†); $CHCl_3$ , HCl (223); hexane (156, † 171, † 606†); $Et_2O$ (606†); Vap. (312, 486, 508, 606†); cf. p. 359
$C_4H_7N_2O$	Creatinine: $H_2O$ (266)	$C_5H_6NO$	$\alpha$ ( $\beta$ , $\gamma$ )-Pyridone: EtOH (+HCl) (+NaOEt) (14)
$C_4H_8$	Isobutylene: Vap. (601, 602)	$C_5H_6$	Cyclopentadiene: EtOH, $Et_2O$ (618); cf. p. 359
$C_4H_8N_2O_2$	Dimethylglyoxime (36); Cu salt (1.5)	$C_5H_6ClN$	Pyridine hydrochloride: $H_2O$ (276†)
$C_4H_8N_2O_3$	<i>d</i> ( <i>l</i> )-Asparagine: $H_2O$ (429†); cf. p. 359	$C_5H_6ClN$	Pyridonium chloride: $H_2O$ , $H_2SO_4$ (241)
$C_4H_8N_2O_3$	Nitrosomethylurethane: $Et_2O$ (247)	$C_5H_6ClN_6O$	Guanine hydrochloride: EtOH (269†)
$C_4H_8N_2O_3$	Urethanediazohydroxide methyl ether: $Et_2O$ (247)	$C_5H_6N_2$	$\alpha$ -Aminopyridine: EtOH (+HCl) (386)
$C_4H_8N_2O_7$	Glyceryl methyl ether dinitrate: $H_2O$ (311)	$C_5H_6N_2O_2$	Aminomethylmaleinimide: EtOH (389)
$C_4H_8O$	Methyl ethyl ketone (54, † 56, † 59, † 62, † 176, 294, 545†); P, $H_2O$ , heptane, $CHCl_3$ (546†); EtOH (538, † 546, † 609); Vap. (538†)	$C_5H_6O_2$	Furfuralcohol (66†); cf. p. 359
$C_4H_8O$	Butyraldehyde (54, † 56, † 59†)	$C_5H_6O_3$	Triketopentane: $CHCl_3$ (410)
$C_4H_8O$	Isobutyraldehyde: <i>v.</i> p. 359	$C_5H_6O_4$	Citraconic acid (58, † 64†); EtOH (607)
$C_4H_8O_2$	Methyl propionate (55, † 57, † 58, † 60†)	$C_5H_6O_4$	Itaconic acid (58†); EtOH (607)
$C_4H_8O_2$	Ethyl acetate (54, † 55, † 56, † 57, † 204, † 309, † 310†); P, EtOH (240, 252); $H_2O$ (240)	$C_5H_6O_4$	Mesaconic acid (58, † 64†); EtOH (607)
$C_4H_8O_2$	<i>n</i> -Butyric acid (54, † 56, † 57, † 60†); P, ligroin (252); $H_2O$ (252, 659, † 660†); EtOH (252, 607); K salt: $H_2O$ (252); Na salt (660†); $H_2O$ (659†)	$C_5H_6O_6$	Acetone-1, 1'-dicarboxylic acid (176)
$C_4H_8O_2$	Propyl formate (55, 57, 60)	$C_5H_7BrO_4$	Dimethyl bromomalonate: EtOH (198)
$C_4H_8OS$	1, 4-Thioxan: EtOH (189)	$C_5H_7NO$	Acetylacetone monoxime anhydride: EtOH (1.5)
$C_4H_8O_2S_2$	Diethylene disulfoxide: $H_2O$ (189)	$C_5H_7NO_2$	Ethyl cyanoacetate: $H_2O$ , EtOH (+NaOH) (82)
$C_4H_8S_2$	Diethylene disulfide: EtOH (189)	$C_5H_7NO_3$	Isonitrosoacetylacetone (400); EtOH (+alk.) (31)
$C_4H_8I$	Isobutyl iodide: EtOH (116)	$C_5H_7N_2O_2$	3, 5-Dimethyl-4-nitropyrazole (554)
$C_4H_8NO$	<i>tert.</i> -Nitrosobutane: $Et_2O$ (25)	$C_5H_7N_2O_3$	Ethyl fulminurate: $H_2O$ (255)
$C_4H_8N_2O_2$	Creatine: <i>v.</i> p. 359	$C_5H_8$	$\beta$ -Methylbutadiene (Isoprene): Vap. (601, 602); cf. p. 359
$C_4H_{10}N_2$	Piperazine: EtOH; Vap. (520†)	$C_5H_8N_2$	3, 5-Dimethylpyrazole (554)
$C_4H_{10}N_2O$	Diethylnitrosoamine: EtOH (25)	$C_5H_8O$	Methyl allyl ketone: $Et_2O$ , Vap. (539)
$C_4H_{10}O$	Ethyl ether (592.3)	$C_5H_8O$	Methyl propenyl ketone: $Et_2O$ , Vap. (539)
$C_4H_{10}O$	<i>n</i> -Butyl alcohol (54, † 56, † 438)	$C_5H_8O_2$	Acetylacetone (24, 62, † 69, † 294, 204, † 370†); EtOH (1.5, 22, 24, 269, † 475, 476, 478); Vap. (538); cf. p. 359; metallic derivatives (22); Al, Be, Th (24); Ba, Ca, Cd, Co, Cr, Cu, Fe, Hg, Li, Sc, Th, Yt, Zn (476); Cu (1.5)
$C_4H_{10}O$	<i>tert.</i> -Butyl alcohol (438)	$C_5H_8O_2$	Allylactic acid (58, † 64, † 66†)
$C_4H_{10}O$	Isobutyl alcohol (237†)	$C_5H_8O_3$	Acetylpropionyl (176)
$C_4H_{10}O_2$	Methyl orthoformate: P, $H_2O$ , EtOH (240)		Ethyl pyruvate (66, † 67, † 68, † 294); EtOH (609)



Formula	Name, solvents and literature	Formula	Name, solvents and literature
Ultra-violet and Visible.—(Continued)			
$C_5H_8O_3$	Methyl acetoacetate (62†)	$C_6H_5Cl_2NO_2S$	4-Chloro-2-nitrophenylsulfur chloride: $CHCl_3$ (174.2†)
$C_5H_8O_3$	Levulinic acid: <i>v. p.</i> 359	$C_6H_5Cl_2N_2O$	2, 3, 4-Trichloropicolinamide (506); Vap. (520)
$C_5H_8O_4$	Dimethyl malonate: $H_2O$ , EtOH (+NaOH) (198); (+NaOH) (+HCl) (82)	$C_6H_5Cl_3O$	2, 4, 6-Trichlorophenol: EtOH, Vap. (519)
$C_5H_9BrN_2O_2$	Bromomalondimethylamide: EtOH (198)	$C_6H_5Cl_3S$	2, 5-Dichlorobenzenesulfur chloride: $CHCl_3$ (174.2†)
$C_5H_9NO_2$	Methylnitrotetramethylene: EtOH (553)	$C_6H_5N_3O_6$	1, 3, 5-Trinitrobenzene: EtOH (34, 218, 249); NaOEt, PhNMe <sub>2</sub> , $C_6H_6$ + ( $C_6H_4:CH$ ) <sub>2</sub> (34); Na salt: EtOH (249); NaOEt (244)
$C_5H_9NO_4$	Glutamic acid: <i>v. p.</i> 359	$C_6H_5N_3O_7$	Picric acid (148.5); $H_2O$ (77, 659†); EtOH (34, 77); heptane, NaOEt, PhNMe <sub>2</sub> , $C_6H_6$ , ( $C_6H_4:CH$ ) <sub>2</sub> , piperidine (34); HCl (34, 86); NaOH (86†); K, Na salts (209); $H_2O$ (659, † 660†)
$C_5H_{10}$	Trimethylethylene: hexane (418); Vap. (602); <i>cf. p.</i> 359	$C_6H_4BrCl$	<i>o</i> ( <i>m</i> , <i>p</i> )-Chlorobromobenzene: EtOH, Vap. (524)
$C_5H_{10}$	Methyltetramethylene: EtOH (553)	$C_6H_4Br_2$	<i>o</i> ( <i>m</i> )-Dibromobenzene: P, † EtOH, † Vap. (515); <i>p</i> -Dibromobenzene: EtOH (386, 524); Vap. (524)
$C_5H_{10}$	Cyclopentane: EtOH (553)	$C_6H_4ClNO$	<i>p</i> -Benzoquinone chloroimide: EtOH (282)
$C_5H_{10}$	Amylene: P, EtOH (261†)	$C_6H_4ClN_3O_2$	<i>p</i> -Nitrobenzenediazonium chloride: $H_2O$ (247)
$C_5H_{10}ClNO_2$	Glutamic acid hydrochloride: EtOH (649)	$C_6H_4Cl_2$	<i>o</i> ( <i>m</i> , <i>p</i> )-Dichlorobenzene (17); P, † Vap. (515, 524); EtOH (28, 515†)
$C_5H_{10}N_2$	Diethylecyanamide: hexane (370, † 371†)	$C_6H_4Cl_2N_2$	<i>p</i> -Benzoquinone dichloroimide: EtOH (282)
$C_5H_{10}N_2O_2$	Nitrosopiperidine: EtOH, Vap. (520)	$C_6H_4Cl_2S$	4-Chlorobenzenesulfur chloride (174.2†)
$C_5H_{10}N_2O_2$	Acetylacetonedioxime (1.5)	$C_6H_4I_2$	<i>o</i> ( <i>m</i> )-Diiodobenzene: P, † EtOH, † Vap. (517)
$C_5H_{10}O$	Diethyl ketone (54, † 56, † 62, † 176, 545†) P, $H_2O$ , heptane, $CHCl_3$ (546†); EtOH (538, 546†); Vap. (538)	$C_6H_4N_2O$	<i>p</i> -Benzoquinonediazide: EtOH (89, 247)
$C_5H_{10}O$	Methyl isopropyl ketone (176, 294, 545†); P, $H_2O$ , heptane, $CHCl_3$ (546†); EtOH (546, † 609)	$C_6H_4N_2O_3$	Oxalosuccinonitrile (175)
$C_5H_{10}O$	Methyl propyl ketone (545†); P, $H_2O$ , heptane, $CHCl_3$ (546†); EtOH (546, † 609)	$C_6H_4N_2O_4$	Pyrazine-2, 3-dicarboxylic acid and Fe, Na salts: $H_2O$ (394)
$C_5H_{10}O$	Cyclopentanol: EtOH (553)	$C_6H_4N_2O_4$	<i>o</i> ( <i>p</i> )-Dinitrobenzene: EtOH (540, 640); <i>m</i> :- P (540†); EtOH (540, 640); hexane (640)
$C_5H_{10}OS_2$	Diethyl dithiocarbonate: EtOH (536)	$C_6H_4N_2O_6$	2, 3(5)-Dinitrophenol (645†)
$C_5H_{10}OS_2$	Ethyl xanthate: EtOH (252, 536); Et <sub>2</sub> O, ligroin (252); K salt: $H_2O$ (252)	$C_6H_4N_2O_6$	2, 6-Dinitrophenol: $H_2O$ , HCl, NaOH (86); Na salt (209†)
$C_5H_{10}O_2$	Propyl acetate (54, † 55, † 56, † 57, † 60†)	$C_6H_4N_2O_6$	2, 4-Dinitrophenol: $H_2O$ (77, 86, 660); EtOH (77); HCl, NaOH (86); Na salt: $H_2O$ (660)
$C_5H_{10}O_2$	<i>n</i> -Valeric acid (57, † 60†)	$C_6H_4N_4O_6$	Picramide: EtOH (472)
$C_5H_{10}O_2$	Isovaleric acid and Na salt: $H_2O$ (659†)	$C_6H_4O_2$	<i>p</i> -Benzoquinone (410, 432, † 594, † 637); $H_2O$ (288, 610); EtOH (36, 234, 244, 288, 405, 406, 409, 411); Et <sub>2</sub> O (288); EtOH + <i>p</i> - $C_6H_4$ -(OH) <sub>2</sub> , PhOH + $CHCl_3$ (234); hexane (356†); Vap. (288, 408, 531); <i>cf. p.</i> 359
$C_5H_{10}O_2$	Methyl butyrate (54, † 57, † 60†)		Dihydroxyquinone: EtOH (409)
$C_5H_{10}O_2$	Ethyl propionate (55, † 57, † 60†)		Bromobenzene: P (514†); EtOH (386, 486, † 514, † 610); Vap. (202, 486, 514, 658)
$C_5H_{10}O_2S$	Diethyl thiocarbonate: EtOH (252, 536†); K salt: $H_2O$ , EtOH (252)	$C_6H_5BrN_2O_4S$	<i>p</i> -Bromobenzenediazonium sulfate: $H_2O$ (247)
$C_5H_{10}O_2S$	Diethyl thioncarbonate: EtOH (252, 536†)	$C_6H_5BrO$	<i>p</i> -Bromophenol: EtOH (385, 519); EtOH + NaOEt (385); Vap. (519)
$C_5H_{10}O_3$	Diethyl carbonate: EtOH (536†)	$C_6H_5Cl$	Chlorobenzene (37†); P (514†); EtOH (77, 20, 386, 486, † 514, † 530); Vap. (202, 301, † 486, 514, 647, 658)
$C_5H_{10}S_3$	Diethyl trithiocarbonate: EtOH (212, † 536); $CHCl_3$ , ligroin (212†)	$C_6H_5Cl_2N_2$	Benzenediazonium chloride: $H_2O$ (247)
$C_5H_{11}I$	Isoamyl iodide: EtOH (116)	$C_6H_5Cl_2N_2O_3S$	<i>o</i> -Chlorobenzene- <i>anti</i> ( <i>syn</i> )-diazosulfonic acid, K salt: $H_2O$ (247)
$C_5H_{11}N$	Piperidine (398†); P (509†); EtOH (263, † 312, † 395, † 509, † 520); (+acid) (520); Vap. (312, † 508)	$C_6H_5ClO$	<i>o</i> -Chlorophenol: EtOH (386, 540); Vap. (540)
$C_5H_{11}NO_2$	Amyl nitrite: EtOH (25); (+EtSH) (259)	$C_6H_5ClO$	<i>m</i> -Chlorophenol: EtOH, Vap. (540)
$C_5H_{12}BrN$	Neurine hydrobromide: <i>v. p.</i> 359	$C_6H_5ClO$	<i>p</i> -Chlorophenol: EtOH (385, 540); EtOH + NaOEt (385); Vap. (540)
$C_5H_{12}ClN$	Piperidine hydrochloride: EtOH (395†)	$C_6H_5Cl_2N$	2, 4-Dichloroaniline: EtOH, acid, Vap. (519)
$C_5H_{12}ClNO_2$	Betaine hydrochloride: <i>v. p.</i> 359	$C_6H_5F$	Fluorobenzene: EtOH (386); Vap. (624)
$C_5H_{12}N_2O_2$	Piperidine hydronitrite: EtOH (259)	$C_6H_5I$	Iodobenzene: P (517†); EtOH (386, 486, † 517†); Vap. (202, † 486, 517)
$C_5H_{12}O$	<i>n</i> ( <i>tert.</i> )-Amyl alcohol (438)	$C_6H_5IO$	<i>p</i> -Iodophenol: EtOH, Vap. (519)
$C_5H_{14}ClNO$	Choline hydrochloride: <i>v. p.</i> 359		
$C_5H_{16}Cl_2N_2$	Cadaverine hydrochloride: <i>v. p.</i> 359		
$C_6Br_4O_2$	Tetrabromobenzoquinone (410)		
$C_6Cl_4O_2$	Tetrachlorobenzoquinone: $CHCl_3$ (403, 409, 411); $C_6(CH_3)_6$ (411)		
$C_6Cl_6$	Hexachlorobenzene (261†); EtOH, Vap. (524†)		
$C_6HCl_3O_2$	Trichlorobenzoquinone: EtOH (409, 610)		
$C_6HCl_6N$	2, 3, 4-Hexachloropicoline (506); Vap. (520)		
$C_6H_2Br_2O_2$	Dibromobenzoquinone (410)		
$C_6H_2Cl_2O_2$	Dichlorobenzoquinone: EtOH (409, 411, 610)		
$C_6H_2Cl_3NO_2$	2, 3, 4-Trichloropicolinic acid (506)		
$C_6H_2BrO_2$	Bromo- <i>p</i> -benzoquinone: EtOH (610)		
$C_6H_2Br_3O$	2, 4, 6-Tribromophenol: EtOH, Vap. (519)		
$C_6H_2ClO_2$	Chlorobenzoquinone: EtOH (409, 610)		



Formula	Name, solvents and literature	Formula	Name, solvents and literature
<b>Ultra-violet and Visible.—(Continued)</b>			
$C_6H_5NO$	Nitrosobenzene: EtOH (25, 26)	$C_6H_5O$ —(Cont'd)	660†; EtOH (27, 281, 351, † 384, 385, 638; CHCl <sub>3</sub> , ligroin (385); hexane (352, † 355, † 370†); pentane, CCl <sub>4</sub> (351†); $C_6H_5CH_2OH$ (350); NaOH (27, 385, 386, 638); HCl (386, 636†); Vap. (161, † 351, 540, 658); cf. p. 359
$C_6H_5NO_2$	Nitrobenzene (37†); P (34, 540†); H <sub>2</sub> O (637); EtOH (20, 34, 118, 434, 486, † 540, 637); hexane (637); PhNMe <sub>2</sub> , H <sub>2</sub> SO <sub>4</sub> (34); Vap. (540)	$C_6H_5O_2$	Catechol: P, Vap. (540); H <sub>2</sub> O (427, 429†); EtOH (267); hexane (352†); cf. p. 359
$C_6H_5NO_2$	<i>p</i> -Nitrosophenol: EtOH (+NaOEt) (26, 282)	$C_6H_5O_2$	Quinol: H <sub>2</sub> O (228, 427, 429†); EtOH (267); NaOH (27); hexane (352†); Vap. (288, 540†); cf. p. 359
$C_6H_5NO_2$	Picolinic acid (388); H <sub>2</sub> O (394); Co salts (388); Fe salt: H <sub>2</sub> O (394)	$C_6H_5O_2$	Resorcinol: H <sub>2</sub> O (427, 429†); EtOH (267); hexane (352†); cf. p. 359
$C_6H_5NO_2$	Nicotinic acid: v. p. 359	$C_6H_5O_2S$	Benzenesulfinic acid and Na salt: EtOH (189)
$C_6H_5NO_2$	<i>o</i> -Nitrophenol (432, † 637, 638, 660); H <sub>2</sub> O (43, 286); EtOH (26, 43, 185, 386†); (+NaOEt) (26, 43, 185); ligroin (43); Vap. (540); Na salt (660)	$C_6H_5O_3$	Pyrogallol: H <sub>2</sub> O (281, 286, 290); HCl, NaOH (290)
$C_6H_5NO_2$	<i>m</i> -Nitrophenol (286, † 432, † 637, 638); H <sub>2</sub> O, ligroin (43); EtOH (+NaOEt) (26, 43)	$C_6H_5O_3$	Phloroglucinol: H <sub>2</sub> O (281, 290); Et <sub>2</sub> O, NaOH, HCl (290)
$C_6H_5NO_2$	<i>p</i> -Nitrophenol (228, 386, † 432, † 637, 638, 660); H <sub>2</sub> O (43, 255, 286); EtOH (26, 43, 77, 185, 255); EtOH + alk. (26, 40, † 43, 185, 255); ligroin (43, 255); Na salt (660)	$C_6H_5O_3S$	Triacetic lactone: EtOH, NaOEt (21)
$C_6H_5NO_4$	Citrazinic acid: H <sub>2</sub> O (14)	$C_6H_5O_3S$	Benzenesulfonic acid (182, † 660); Na salt (182†)
$C_6H_5NO_5S$	<i>m</i> -Nitrobenzenesulfonic acid: H <sub>2</sub> SO <sub>4</sub> (34)	$C_6H_5O_6$	Aconitic acid (58, † 64†); EtOH (607); cf. p. 359
$C_6H_5N$	Triazobenzene: v. p. 359	$C_6H_5S$	Phenylmercaptan: EtOH (161, 536†); NaOH, Vap. (161)
$C_6H_5N_2O$	<i>p</i> -Nitrobenzenenitrosoamine: CHCl <sub>3</sub> (247)	$C_6H_7BrN_2$	<i>p</i> -Bromophenylhydrazine: EtOH, HCl (40)
$C_6H_5N_2O$	<i>p</i> -Nitrobenzenediazonium hydroxide: Et <sub>2</sub> O, KOH (247)	$C_6H_7N$	$\alpha$ -Picoline (14, † 506); P (509†); EtOH (312†); Vap. (312, 508)
$C_6H_5N_2O$	2, 4-Dinitroaniline: EtOH (477)	$C_6H_7N$	$\beta$ -Picoline (14†); EtOH, Vap. (312†)
$C_6H_5N_2O$	3, 5-Dinitroaniline: EtOH (218)	$C_6H_7N$	Picoline (263); EtOH (262)
$C_6H_5N_2O$	4, 6-Dinitro-3-aminophenol: EtOH (477)	$C_6H_7N$	Aniline (37, † 38, † 530); P (510); H <sub>2</sub> O (286†); EtOH (20, 286, 386, † 395, 410, 486†); hexane (354†); HCl (20, 386†); NaOEt (386†); Vap. (202, 358, 486, 510, 658); cf. p. 359
$C_6H_5N_2O$	Picramic acid: EtOH, HCl, NaOH (453)	$C_6H_7NO$	<i>m</i> -Aminophenol: EtOH, Vap. (519)
$C_6H_5N_2O$	Isopicramic acid: EtOH, HCl, NaOH (453)	$C_6H_7NO$	<i>p</i> -Aminophenol: EtOH, EtOH + NaOH + Na <sub>2</sub> SO <sub>3</sub> , HCl (27)
$C_6H_5$	Benzene (132, † 191, † 299, 300, 386, 530, 592.3); P (486); EtOH (20, 271, † 274, † 286, 335, † 431, † 443, † 483.5, 486†); hexane (156, † 171, 604†); Vap. (170, 202, 271, 300, 483.5, 486, 584, 599, 601, 606, † 658); cf. p. 359	$C_6H_7NO$	$\alpha$ -Methyl- $\beta$ -pyridone (14)
$C_6H_5$	Dipropargyl: EtOH, Vap. (600, 601)	$C_6H_7NO_2$	Pyrocinchonimide: H <sub>2</sub> O, EtOH (389)
$C_6H_5$	Dimethyldiacetylene (423)	$C_6H_7NO_2$	Nitro- <i>m</i> -phenylenediamine: EtOH (218)
$C_6H_5BrN$	<i>o</i> ( <i>m</i> , <i>p</i> †)-Bromoaniline: EtOH (+acid), Vap. † (519)	$C_6H_7NO_2$	Nitro- <i>p</i> -phenylenediamine: EtOH (477)
$C_6H_5ClN$	<i>o</i> ( <i>m</i> , <i>p</i> )-Chloroaniline: EtOH (+acid) (28); Vap. (540)	$C_6H_7NO_2$	<i>p</i> -Nitrophenylhydrazine: EtOH (40)
$C_6H_5Cl_6$	Hexachlorocyclohexane: EtOH, Vap. (524†)	$C_6H_7NO_4$	Dimethylviolic acid: EtOH (+HCl) (+KOEt) (+LiOEt) (+NaOEt) (251); Cs, K, Li, Na, Pb salts: phenol, benzene (251)
$C_6H_5IN$	<i>o</i> ( <i>m</i> , <i>p</i> )-Iodoaniline: EtOH, (+acid), Vap. (519)	$C_6H_7N_2O_6$	Dimethylnitrobarbituric acid: H <sub>2</sub> O, H <sub>2</sub> SO <sub>4</sub> , NaOH (255)
$C_6H_5N_2O$	Benzenediazonium hydroxide, K salt (147); Na salt (247)	$C_6H_8$	Hexatriene (42, 423)
$C_6H_5N_2O$	Benzene- <i>anti</i> -diazonium hydroxide, Na salt (247)	$C_6H_8$	$\Delta^{1,3}$ -Cyclohexadiene (663); Vap. (599, 601)
$C_6H_5N_2OS$	Thionylphenylhydrazine: EtOH (334)	$C_6H_8$	$\Delta^{1,4}$ -Cyclohexadiene (663)
$C_6H_5N_2O_2$	<i>o</i> -Nitroaniline (386†); EtOH (90, 472, 540); (+HCl) (+NaOH) (90); Vap. (540)	$C_6H_8BrN$	Pyridine methobromide: EtOH (223)
$C_6H_5N_2O_2$	<i>m</i> -Nitroaniline: H <sub>2</sub> O (286); EtOH (26, 43)	$C_6H_8ClN$	Pyridine methochloride: H <sub>2</sub> O (223, 228, 241, 242); EtOH (223)
$C_6H_5N_2O_2$	<i>p</i> -Nitroaniline: H <sub>2</sub> O (286); EtOH (26, 43, 90); HCl (26, 90); NaOH (90)	$C_6H_8ClN$	Aniline hydrochloride (395)
$C_6H_5N_2O_2$	<i>p</i> -Benzoquinonedioxime, EtOH (282)	$C_6H_8ClN$	$\alpha$ -Picoline hydrochloride (506)
$C_6H_5N_2O_2$	$\alpha$ -Amino- $\beta$ -pyridinecarboxylic acid: EtOH (386)	$C_6H_8IN$	Pyridine methiodide: H <sub>2</sub> O (228, 242); EtOH, CHCl <sub>3</sub> , $C_6H_5OH$ (223, 228)
$C_6H_5N_2O_3$	2(2, 3, 4, 5)-Nitro-4(5, 4, 3, 2)-aminophenol: EtOH (477)	$C_6H_8N_2$	Benzeneazomethane (247); EtOH (621); EtOH + CHCl <sub>3</sub> (40)
$C_6H_5N_2O_3S$	Benzene- <i>anti</i> ( <i>syn</i> )-diazosulfonic acids, K, Na salts: H <sub>2</sub> O (147, 247)	$C_6H_8N_2$	2, 5-Dimethylpyrazine: EtOH (279)
$C_6H_5N_2O_3S$	<i>p</i> -Sulfo benzene- <i>anti</i> ( <i>syn</i> )-diazonium hydroxide, K, Na salts (147)	$C_6H_8N_2$	Phenylhydrazine: EtOH (40, 512†); HCl (40)
$C_6H_5O$	Phenol (530, 636, 637, 642); P (351, † 540); H <sub>2</sub> O (286, 350, 351, † 385, 636, † 638, 659, †	$C_6H_8N_2$	<i>o</i> ( <i>m</i> )-Phenylenediamine (642)
		$C_6H_8N_2$	<i>p</i> -Phenylenediamine: EtOH (521, 642); Vap. (521)
		$C_6H_8O_2$	Dihydroresorcinol (176); Derivatives (27†)



Formula	Name, solvents and literature	Formula	Name, solvents and literature
Ultra-violet and Visible.—(Continued)			
$C_6H_8O_2$	1, 4-Diketohexamethylene: EtOH (273†)	$C_6H_{12}$	Hexylene: Vap. (600)
$C_6H_8O_2$	Dimethyldiketotetramethylene (371†); $H_2O$ , EtOH (370†)	$C_6H_{12}$	Methylcyclopentane: EtOH (664)
$C_6H_8O_4$	Ethyl acetylglaxyolate (66†)	$C_6H_{12}O$	Methyl butyl ketone (59,† 62,† 545†); P, $H_2O$ , EtOH, heptane, $CHCl_3$ (546†)
$C_6H_8O_4$	Ethyl diketobutyrate (69†)	$C_6H_{12}O$	Methyl isobutyl ketone (59,† 62,† 66,† 67,† 176, 294, 545†); P, $H_2O$ , EtOH, heptane, $CHCl_3$ (546†); cf. p. 360
$C_6H_8O_4$	Lactide: $CHCl_3$ (134)	$C_6H_{12}O$	Methyl <i>tert.</i> -butyl ketone (59,† 62,† 294, 545,† 601); EtOH (546,† 609); $CHCl_3$ , heptane (546†)
$C_6H_8O_6$	Dimethyl oxaloacetate: $H_2O$ , HCl, MeOH, EtOH, $Et_2O$ , ligroin (237); Na salt: $H_2O$ , $Na_2CO_3$ , $NaOCH_3$ (237)	$C_6H_{12}O$	Ethyl propyl ketone (59,† 62,† 545†); P, $H_2O$ , EtOH, heptane, $CHCl_3$ (546†)
$C_6H_8O_6$	Tricarballic acid (58,† 64†); EtOH (607); cf. p. 359	$C_6H_{12}OS_2$	Ethyl ethylthiolthioacetate: EtOH (536†)
$C_6H_8O_7$	Citric acid (58†)	$C_6H_{12}O_2$	Butyl acetate (54,† 55,† 56,† 57†)
$C_6H_9N_3O_2$	Histidine: v. p. 359	$C_6H_{12}O_2$	Ethyl butyrate (55,† 57,† 60†)
$C_6H_9N_3O_3$	Trimethyl isocyanurate: $H_2O$ (80)	$C_6H_{12}O_2$	Propyl propionate (60†)
$C_6H_{10}$	Cyclohexene (592.3, 663); P, Vap. (599); EtOH (279, 599)	$C_6H_{12}O_2$	Methyl valerate (55,† 57,† 60†)
$C_6H_{10}$	2, 4-Hexadiene: Vap. (601, 602)	$C_6H_{12}O_2S$	Ethyl ethylthiolacetate: EtOH (536†)
$C_6H_{10}$	Diallyl: Vap. (602); cf. p. 359	$C_6H_{12}O_3$	Paraldehyde (534,† 571); cf. p. 360
$C_6H_{10}$	$\alpha$ , $\alpha(\beta$ , $\gamma)$ -Dimethylbutadiene: Vap. (602); cf. p. 359	$C_6H_{12}O_6$	Levulose: $H_2O$ (532)
$C_6H_{10}ClN_3O_2$	Histidine hydrochloride: 50% EtOH (649†)	$C_6H_{12}O_6$	Dextrose (265,† 594); $H_2O$ (532)
$C_6H_{10}N_2$	1, 3, 5 (and 3, 4, 5)-Trimethylpyrazole (554)	$C_6H_{12}S_3$	Trithioacetaldehyde (534†)
$C_6H_{10}O$	Mesityl oxide (66,† 67,† 68,† 69,† 176, 294, 574†); $H_2O$ (204†); EtOH (82, 204,† 539); hexane (204,† 573†); MeOH, $CaCl_2$ soln. (573†); Vap. (539); cf. p. 360	$C_6H_{13}ClN_2O_4S_2$	Cystine hydrochloride: 50% EtOH (649†)
$C_6H_{10}O$	Diethylketene: hexane (370,† 371†); cf. p. 360	$C_6H_{13}NO_2$	Leucine (594†); cf. p. 360
$C_6H_{10}O$	Cyclohexanone (66,† 176, 294)	$C_6H_{14}N_2$	$\beta(\gamma)$ -Dimethylpiperazine: EtOH,† Vap. (520)
$C_6H_{10}O$	Allylacetone (59,† 66,† 67,† 69†); EtOH, Vap. (539)	$C_6H_{14}N_2O_2$	Lysine: v. p. 360
$C_6H_{10}O_2$	Acetylmethylacetic acid, vanadyl salt: EtOH (475)	$C_6H_{14}N_4O_2$	Arginine: v. p. 360
$C_6H_{10}O_2$	Ethyl crotonate (68†); EtOH (252); $H_2O$ , hexane (204†); cf. p. 360	$C_6H_{14}O$	Hexyl alcohol (438)
$C_6H_{10}O_2$	Methylacetylacetone (24, 69,† 176); $H_2O$ , hexane (204†); EtOH (204,† 475, 478); cf. p. 360	$C_6H_{14}O$	Methyl <i>n</i> -amyl ether (592.3)
$C_6H_{10}O_2$	Acetonylacetone (59,† 62,† 66†); EtOH (23,† 609); alk. (609); cf. p. 360	$C_6H_{14}O_2$	Acetal (534†)
$C_6H_{10}O_2S_2$	Diethyl dithiooxalate: EtOH (536)	$C_6H_{14}S_2$	<i>S</i> -Diethylthioethane: EtOH (536)
$C_6H_{10}O_2S_3$	Xanthic thioanhydride: EtOH (252)	$C_6H_{15}IS$	Triethylsulfonium iodide: $CHCl_3$ , EtOH (242)
$C_6H_{10}O_3$	Ethyl acetoacetate (22, 59,† 62,† 68,† 255†); P (220); $H_2O$ (33,† 220, 228, 609); EtOH (24, 33,† 220, 228, 478, 609); $Et_2O$ (228); hexane (220, 228); ligroin (222); MeOH (228); alk. (22, 24, 220, 228, 294, 385); HCl (22, 220, 228); cf. p. 360; Al derivatives: EtOH (22)	$C_6H_{15}N$	Triethylamine (63,† 395†)
$C_6H_{10}O_3$	$\beta$ -Ethoxycrotonic acid and Na salt: EtOH (252)	$C_6H_{15}N$	Dipropylamine (63†)
$C_6H_{10}O_3S$	Diethyl thiooxalate: EtOH (536)	$C_6H_{16}ClN$	Triethylamine hydrochloride (395†)
$C_6H_{10}O_4$	Diethyl oxalate: P, ligroin (252); EtOH (252, 536†)	$C_7H_2Br_3N_3$	Tribromobenzene- <i>anti</i> ( <i>syn</i> )-diazonium cyanide: $Et_2O$ (247)
$C_6H_{10}O_5$	Dilactylic acid: $CHCl_3$ (134)	$C_7H_3Cl_2NO_2$	Quinolinyl chloride: $Et_2O$ (578)
$C_6H_{10}O_5$	Lactic anhydride: $CHCl_3$ (134)	$C_7H_3Cl_3O_2$	Trichlorotoluquinone: EtOH (610)
$C_6H_{11}BrN_2O_2$	Bromural: v. p. 360	$C_7H_4ClN_3$	<i>p</i> -Chlorobenzenediazonium cyanide (147)
$C_6H_{11}NO_2$	$\alpha$ , $\alpha$ -Methylnitrocyclopentane: EtOH (553, 664)	$C_7H_4Cl_2O_3S$	<i>o</i> -Sulfobenzoic acid dichloride: $Et_2O$ (578)
$C_6H_{11}NO_2$	Nitrocyclohexane: EtOH, $CH_3ONa$ (664)	$C_7H_4Cl_3NO_2$	Methyl 2, 3, 4-trichloropicolinic acid (506)
$C_6H_{11}NO_2$	Nitrosoisopropylacetone (228); $H_2O$ , EtOH (25)	$C_7H_4O_6$	Chelidonic acid, Na salts: $H_2O$ (21)
$C_6H_{11}NO_2$	Cyclopentyl nitromethane: EtOH, $NaOEt$ (553)	$C_7H_5BrN_2O_4$	Phenylbromodinitromethane: EtOH (198)
$C_6H_{11}NO_2$	Ethyl $\beta$ -aminocrotonate: EtOH, HCl (22)	$C_7H_5BrO_2$	<i>p</i> -Bromobenzoic acid and Na salt: EtOH, $NaOH$ (317)
$C_6H_{12}$	Cyclohexane (664); EtOH (279)	$C_7H_5Br_3O$	Tribromophenyl methyl ether: EtOH, HCl (406)
		$C_7H_5ClO$	Benzoyl chloride: EtOH (523)
		$C_7H_5ClO$	<i>o</i> ( <i>m</i> , <i>p</i> )-Chlorobenzaldehyde: EtOH, Vap. (523)
		$C_7H_5ClO_2$	<i>o</i> ( <i>m</i> )-Chlorobenzoic acid (527); EtOH (576)
		$C_7H_5ClO_2$	<i>p</i> -Chlorobenzoic acid (527)
		$C_7H_5Cl_2N_3O_2$	3, 5-Dichloro-4-hydroxybenzeneazofornamide: EtOH, $NaOH$ (293)
		$C_7H_5Cl_2$	Benzotrichloride (642)
		$C_7H_5IO_2$	<i>o</i> ( <i>m</i> , <i>p</i> )-Iodobenzoic acid (527)
		$C_7H_5N$	Benzonitrile (20, 37,† 530); EtOH (524); Vap. (524, 624)
		$C_7H_5NO$	Phenyl isocyanate: hexane (370,† 371†)
		$C_7H_5NO$	Anthranil: EtOH, $Et_2O$ , hexane (575)
		$C_7H_5NO_2$	<i>o</i> -Oxycarbanil (479†); EtOH (283)
		$C_7H_5NO_3$	<i>o</i> ( <i>m</i> , <i>p</i> )-Nitrobenzaldehyde (640); EtOH, Vap. (540)



Formula	Name, solvents and literature	Formula	Name, solvents and literature
<b>Ultra-violet and Visible.—(Continued)</b>			
$C_7H_5NO_3S$	Saccharin: $H_2O$ (134)	$C_7H_7Cl$	<i>p</i> -Chlorotoluene (17, 386†); EtOH (28)
$C_7H_5NO_4$	Quinolinic acid: $H_2O$ (394); EtOH (262, 578); cf. p. 360	$C_7H_7ClS$	<i>p</i> -Chlorobenzylmercaptan: ligroin (212†)
$C_7H_5NO_4$	Lutidinic acid (262)	$C_7H_7Cl_2NO_2S$	Toluene- <i>p</i> -sulfonedichloramide: EtOH (199)
$C_7H_5NO_4$	<i>o</i> ( <i>m</i> )-Nitrobenzoic acid (527)	$C_7H_7I$	<i>o</i> ( <i>m</i> )-Iodotoluene: P, † EtOH, † Vap. (517)
$C_7H_5NO_4$	<i>p</i> -Nitrobenzoic acid (527); EtOH, NaOH (317)	$C_7H_7NO$	Benzamide: EtOH (285)
$C_7H_5N_2O_7$	2, 4, 6-Trinitroanisole: EtOH (34, 86); various solns. (34)	$C_7H_7NO$	<i>o</i> -Aminobenzaldehyde: EtOH, EtOH + HCl (30)
$C_7H_5N_2O_8$	Picrylmethylnitroamine: EtOH, KOH (165)	$C_7H_7NO$	<i>p</i> -Aminobenzaldehyde: EtOH (30, 519); Et- OH + HCl (30); Vap. (519)
$C_7H_5ClNO_2$	Chlorotoluquinone oxime: EtOH (217); K salt: EtOH + KOH (217)	$C_7H_7NO$	<i>anti</i> ( <i>syn</i> )-Benzaldoxime (637, 639, 642); EtOH (80, 523); NaOEt (80); Et <sub>2</sub> O (278); Vap. (523)
$C_7H_5ClN_2O_2$	3-Chloro-4-hydroxybenzeneazoformamide: Et- OH, EtOH + NaOH (293)	$C_7H_7NO_2$	<i>o</i> ( <i>m</i> , <i>p</i> )-Nitrotoluene: Vap. (540); EtOH (42, 637)
$C_7H_5Cl_2$	Benzylidene chloride (642); EtOH, Vap. (523)	$C_7H_7NO_2$	Phenylnitromethane (228, 664); EtOH, Et <sub>2</sub> O, MeOEt (255)
$C_7H_5N_2$	Phenyldiazomethane: v. p. 360	$C_7H_7NO_2$	<i>o</i> ( <i>m</i> , <i>p</i> )-Aminobenzoic acid (428†); $H_2O$ (429)
$C_7H_5N_2O_3$	<i>p</i> -Nitro- <i>anti</i> ( <i>syn</i> )-benzaldoxime: EtOH (80, 217); NaOEt (80)	$C_7H_7NO_3$	<i>o</i> -Nitroanisole (540, 637); EtOH (26, 32, 43); $H_2SO_4$ (32); ligroin (43); Vap. (540)
$C_7H_5N_2O_4$	Phenyldinitromethane: EtOH, $CHCl_3$ (259, 291); K salt: $H_2O$ (198, 259, 291)	$C_7H_7NO_3$	<i>m</i> -Nitroanisole (637)
$C_7H_5N_2O_4$	<i>o</i> ( <i>m</i> , <i>p</i> )-Nitrophenylnitromethane: EtOH, $CHCl_3$ (291); K salt: $H_2O$ (291)	$C_7H_7NO_3$	<i>p</i> -Nitroanisole (26, 637); EtOH (26, 32); $H_2SO_4$ (32); Vap. (540)
$C_7H_5N_4O_5$	3, 5-Dinitro- <i>p</i> -tolylnitrosoamine: EtOH (471, 472)	$C_7H_7NO_3$	Nitro- <i>p</i> -cresol: EtOH (+NaOEt) (43)
$C_7H_5N_4O_6$	Picrylmethylamide: EtOH, KOH (165)	$C_7H_7NS$	Thiobenzamide: $H_2O$ (252)
$C_7H_5N_4O_7$	2, 3, 5-Trinitroaminoanisole (453)	$C_7H_7N_2O$	Phenylazocarbamide (247)
$C_7H_5O$	Benzaldehyde (37, † 38, † 66, † 534, 637); EtOH (20, 540, 604, † 636†); EtOH, HCl, $CHCl_3$ (636†); Vap. (540, 624); cf. p. 360	$C_7H_7N_2O_2$	Quinonemonosemicarbazone: EtOH (+NaOH) (293)
$C_7H_5OS$	Thiobenzoic acid: $H_2O$ , EtOH (252); Hg, K salts: EtOH (252)	$C_7H_7N_2O_3$	<i>p</i> -Nitrobenzenemethylnitrosoamine: EtOH (247)
$C_7H_5O_2$	<i>o</i> -Hydroxybenzaldehyde (38, † 637); EtOH (39, † 523, 634, 636, † 638); $H_2O$ , HCl, $CHCl_3$ (636†); NaOEt (634); Vap. (523)	$C_7H_7N_2O_3$	<i>p</i> -Nitrobenzenediazonium hydroxide methyl ether (247)
$C_7H_5O_2$	<i>m</i> -Hydroxybenzaldehyde (636, 638); $H_2O$ , HCl (636†); EtOH (523, 636†); Vap. (523)	$C_7H_7N_2O_4$	2, 4-Dinitromethylaniline: EtOH (477)
$C_7H_5O_2$	<i>p</i> -Hydroxybenzaldehyde (636, 638); $H_2O$ , HCl (636); EtOH (523, 634, 636); NaOEt (634); Vap. (523)	$C_7H_7N_3O_4$	Dinitro- <i>o</i> ( <i>m</i> )-toluidine: EtOH (477)
$C_7H_5O_2$	Benzoic acid (182, † 527, 645.5†); $H_2O$ (286); EtOH (136, 238, 285, 317, 384, 457); hexane (95, † 96, † 606†); $H_2SO_4$ (238); NaOH (317); Vap. (624); cf. p. 360; Ag, K salts: $H_2O$ (285); Na salts: $H_2O$ (182, † 659†)	$C_7H_7N_3O_4$	2(3), 6(5)-Dinitro- <i>p</i> -toluidine: EtOH (472)
$C_7H_5O_2$	Toluquinone (36); EtOH (409, 410); Vap. (531); cf. p. 360	$C_7H_7N_3O_5$	2, 6-Dinitro-4-aminoanisole: EtOH, HCl (453)
$C_7H_5O_2$	Salicylic acid: $H_2O$ (182, † 286, 427, 429, 659†); EtOH (267, 384, 386); hexane + Et <sub>2</sub> O (96†); Na salt: $H_2O$ (182, † 659, † 660†); EtOH (386); cf. p. 360	$C_7H_8$	Toluene (20, † 37, † 133, 202, † 530, 642); P (486, 515†); EtOH (386, † 443, † 483.5, 486); hexane (353, † 355†); Vap. (111, 202, 271, 483.5, 486, 647, 658); cf. p. 360
$C_7H_5O_2$	<i>m</i> -Hydroxybenzoic acid: $H_2O$ (427, 429); EtOH (267, 386); hexane + Et <sub>2</sub> O (96†); cf. p. 360	$C_7H_8ClN$	Chlorolutidine (504)
$C_7H_5O_2$	<i>p</i> -Hydroxybenzoic acid: $H_2O$ (286, 427, 429); EtOH, (267, 386); hexane + Et <sub>2</sub> O (96†); cf. p. 360; Na salt (660†); EtOH (386)	$C_7H_8ClNO_2S$	Toluene- <i>p</i> -sulfonechloramide: EtOH (199)
$C_7H_5O_2S$	<i>o</i> -Sulfobenzoic acid: EtOH (578); $NH_4$ salt: $H_2O$ (134)	$C_7H_8N_2$	Formaldehyde phenylhydrazine: EtOH (40)
$C_7H_7Br$	<i>o</i> ( <i>m</i> )-Bromotoluene: P, EtOH, Vap. (515)	$C_7H_8N_2O$	<i>o</i> -Aminobenzaldoxime: EtOH + HCl (30)
$C_7H_7BrO$	<i>p</i> -Bromoanisole: EtOH, Vap. (526)	$C_7H_8N_2O$	Phenylmethylnitrosoamine (147); EtOH (25)
$C_7H_7Cl$	Benzyl chloride (642); EtOH, Vap. (524)	$C_7H_8N_2OS$	Thionylmethylphenylhydrazine: EtOH (334)
$C_7H_7Cl$	<i>o</i> -Chlorotoluene (17, 386†); P, † Vap. (515); EtOH (28, 515†)	$C_7H_8N_2O_2$	3-Nitro- <i>p</i> -toluidine: EtOH (43)
$C_7H_7Cl$	<i>m</i> -Chlorotoluene (17); P, † Vap. (515); EtOH (28, 515†)	$C_7H_8N_2O_2$	Nitrotoluidine (9 forms): EtOH (477)
		$C_7H_8N_2O_4S$	Nitrotoluene- <i>p</i> -sulfonamide: EtOH (+NaOEt) (199)
		$C_7H_8N_4O_2$	Theobromine (129, † 269†); cf. p. 360
		$C_7H_8N_4O_2$	Theophylline (129†); cf. p. 360
		$C_7H_8O$	Benzyl alcohol (20, † 37, † 642); $H_2O$ , $C_6H_5OH$ (350); Vap. (524, 624)
		$C_7H_8O$	Anisole (20, 37, † 150, † 636†); EtOH (27, 32, 386, † 526†); $H_2SO_4$ (32); $CHCl_3$ (537); Vap. (526, † 537)
		$C_7H_8O$	<i>o</i> -Cresol (660†); P, † Vap. (540); EtOH (27, 220, 267); alk. (27, 220); hexane (355†); cf. p. 360; Na salt: $H_2O$ (660†)
		$C_7H_8O$	<i>m</i> -Cresol: EtOH (267); (+NaOH) (27); Vap. (540); cf. p. 360
		$C_7H_8O$	<i>p</i> -Cresol (660†); P, † Vap. (540); EtOH (27, 267); (+NaOH) (27); hexane (355†); cf. p. 360; Na salt: $H_2O$ (660†)



Formula	Name, solvents and literature	Formula	Name, solvents and literature
Ultra-violet and Visible.—(Continued)			
$C_7H_8OS$	Ketothiodimethylpyrone: EtOH, Et <sub>2</sub> O, H <sub>2</sub> SO <sub>4</sub> (241)	$C_7H_{14}O_2$	Propyl butyrate (60†)
$C_7H_8O_2$	Dimethylpyrone (76); EtOH (21, 76, 241); NaOH, HCl (21)	$C_7H_{14}O_2$	Amyl acetate: P, ligroin, EtOH (252)
$C_7H_8O_2$	Guaiacol: P, † Vap. (540); H <sub>2</sub> O (636, † 638, 660†); EtOH (27, 636, † 638); (+NaOH) (27)	$C_7H_{16}O$	Heptyl alcohol (438†)
$C_7H_8O_2$	Resorcinol monomethyl ether (27†); H <sub>2</sub> O, EtOH (636†)	$C_7H_{16}O_2$	Ethyl orthoformate and salts (240, 252); K salt: H <sub>2</sub> O (252)
$C_7H_8O_2$	Hydroquinol methyl ether (27†)	$C_8H_4Cl_2O_2$	Phthalyl chloride: Et <sub>2</sub> O, hexane (577)
$C_7H_8O_2S$	Phenylmethylsulfone: EtOH (189)	$C_8H_4Cl_2O_6$	<i>p</i> -Dichlorodioxytetraphthalic acid: H <sub>2</sub> O, EtOH, Et <sub>2</sub> O, HCl (236)
$C_7H_8O_3S$	Toluene- <i>o</i> -sulfonic acid: H <sub>2</sub> O (578)	$C_8H_4O_3$	Phthalic anhydride: EtOH (284); AcOH, H <sub>2</sub> SO <sub>4</sub> (500)
$C_7H_8O_4S$	Hydroxybenzylsulfonic acid: EtOH (523†)	$C_8H_5NO_2$	Isatin (36, † 479, † 648†); EtOH (275); various solvents (435†)
$C_7H_9N$	Benzylamine (642); P, EtOH, Vap. (510)	$C_8H_5NO_2$	<i>o</i> ( <i>m</i> )-Cyanobenzoic acid: EtOH, NaOEt (576)
$C_7H_9N$	<i>o</i> -Toluidine (386†); P, Vap. (510); EtOH (263†); EtOH + acid (28); hexane (354†); cf. p. 360	$C_8H_5NO_2$	Phthalimide (386†); EtOH (284, 500); H <sub>2</sub> SO <sub>4</sub> (500)
$C_7H_9N$	<i>m</i> -Toluidine (386†); P, Vap. (510); EtOH (+acid) (28); cf. p. 360	$C_8H_5NO_3$	Anthroxanic acid: EtOH, Et <sub>2</sub> O, HCl (575)
$C_7H_9N$	<i>p</i> -Toluidine (507); acid (28, 263†); hexane (354†); cf. p. 360	$C_8H_5NO_3$	Phthaloxime (500)
$C_7H_9N$	Methylaniline: P, Vap. (510); EtOH (20)	$C_8H_6$	Phenylacetylene (423, 619); EtOH (386)
$C_7H_9N$	2, 4-Lutidine: Vap. (508)	$C_8H_6N_2O_2$	<i>p</i> -Nitrobenzyl cyanide and K, Na salts: EtOH (405); K, Na salts: EtOH, MeOH (405)
$C_7H_9N$	2, 6-Lutidine (14); Vap. (508)	$C_8H_6N_2O_2$	<i>p</i> -Nitrophenylacetonitrile: EtOH, NaOH (317)
$C_7H_9NO$	$\gamma$ -Lutidone: EtOH (+HCl) (+NaOEt) (14)	$C_8H_6N_2O_2$	Nitrosophthalimide: EtOH, NaOEt (500)
$C_7H_9NO$	<i>o</i> ( <i>p</i> )-Anisidine: EtOH (+HCl) (27, 386†); Vap. (526)	$C_8H_6N_2O_2$	Phenylcyanonitromethane: EtOH (255); Na salt: H <sub>2</sub> O (255)
$C_7H_9NO_2S$	<i>p</i> -Toluenesulfonamide: EtOH (199)	$C_8H_6N_4O_8$	Alloxantin: H <sub>2</sub> O (269†)
$C_7H_9N_4O_2$	4-Nitro-2, 5-tolylenediamine: EtOH (477)	$C_8H_6N_4O_8$	2, 3, 5-Trinitro-4-acetylaminophenol: EtOH (+alk.) (455)
$C_7H_{10}BrNO_6$	Diethyl bromonitromalonate: EtOH (198, 255)	$C_8H_6O_2$	<i>o</i> ( <i>m</i> , <i>p</i> )-Phthalic aldehyde (640); EtOH, Vap. (523)
$C_7H_{10}Br_2O_4$	Diethyl dibromomalonate: EtOH (198)	$C_8H_6O_2$	Phthalide (386); EtOH, H <sub>2</sub> SO <sub>4</sub> , NaOH (500)
$C_7H_{10}ClN$	<i>o</i> ( <i>p</i> )-Toluidine hydrochloride: EtOH (263)	$C_8H_6O_3$	Piperonal: EtOH, Vap. (533)
$C_7H_{10}ClN$	2, 6-Lutidine hydrochloride (14)	$C_8H_6O_4$	Phthalic acid (386†); H <sub>2</sub> O (284, 286, 429); EtOH, H <sub>2</sub> SO <sub>4</sub> (500)
$C_7H_{10}INO$	Pyridonium ethiodide: H <sub>2</sub> O, CHCl <sub>3</sub> (242)	$C_8H_6O_4$	Isophthalic acid: H <sub>2</sub> O (429); EtOH (284); K salt: H <sub>2</sub> O (284)
$C_7H_{10}N_2O_2$	Methylaminomethylmaleinmethylimide: EtOH, HCl (389)	$C_8H_6O_4$	Terephthalic acid (284); H <sub>2</sub> O (429); K salt (284)
$C_7H_{10}N_2O_4$	Diethyl diazomalonate: v. p. 360	$C_8H_6O_4$	Piperonylic acid (287); EtOH (140, 533); Vap. (533)
$C_7H_{10}O_3$	Diacetylacetone: H <sub>2</sub> O, EtOH, alk. (21)	$C_8H_6O_6$	Dihydroxyterephthalic acid: MeOH (236)
$C_7H_{10}O_6S$	Dimethylpyrone sulfate: H <sub>2</sub> SO <sub>4</sub> (241)	$C_8H_7Cl$	$\alpha$ ( $\omega$ )-Chlorostyrene: EtOH (393)
$C_7H_{11}BrO_4$	Diethyl bromomalonate: EtOH (198)	$C_8H_7ClS_3$	<i>p</i> -Chlorobenzyltrithiocarbonic acid: ligroin (212); K salt: H <sub>2</sub> O (212)
$C_7H_{11}ClO_4$	Diethyl chloromalonate: EtOH (198)	$C_8H_7N$	Indole (648†); hexane (171†); v. p. 360
$C_7H_{11}N$	1, 2, 5-Trimethylpyrrole (362)	$C_8H_7N$	Phenylacetonitrile (37†); EtOH (317, 524); NaOH (317); Vap. (524)
$C_7H_{11}NO_5$	Diethyl isonitrosomalonate: EtOH (+alk.) (31)	$C_8H_7N$	<i>o</i> ( <i>p</i> )-Tolunitrile (386†); EtOH (28, 524); Vap. (524)
$C_7H_{11}NO_6$	Diethyl nitromalonate: EtOH (198, 255); H <sub>2</sub> O, H <sub>2</sub> SO <sub>4</sub> , CH <sub>3</sub> OH, CHCl <sub>3</sub> , Et <sub>2</sub> O (255)	$C_8H_7N$	<i>m</i> -Tolunitrile: EtOH (28, 524); Vap. (524)
$C_7H_{12}O$	Suberone: v. p. 360	$C_8H_7NO$	Phthalimidine: EtOH, H <sub>2</sub> SO <sub>4</sub> (500)
$C_7H_{12}O$	<i>o</i> ( <i>p</i> )-Methylcyclohexanone (294)	$C_8H_7NO$	Mandelonitrile: EtOH (523†)
$C_7H_{12}O$	<i>m</i> -Methylcyclohexanone (176, 294)	$C_8H_7NO$	Methylantranil: H <sub>2</sub> O, HCl (+ EtOH), Et <sub>2</sub> O, hexane (575)
$C_7H_{12}O_2$	Dimethylacetylacetone (176)	$C_8H_7NO_2$	$\alpha$ , $\beta$ -Dioxindol (648†)
$C_7H_{12}O_2S_2$	Diethyl dithiomalonate: EtOH (536†)	$C_8H_7NO_2$	$\omega$ -Nitrostyrene: EtOH (25)
$C_7H_{12}O_3$	Ethyl methylacetoacetate: EtOH, hexane, NaOEt, H <sub>2</sub> O (220)	$C_8H_7NO_4$	<i>p</i> -Nitrophenylacetic acid: EtOH (+ NaOH) (317)
$C_7H_{12}O_3$	Ethyl levulinate (66, † 67, † 68†); EtOH (609)	$C_8H_7NO_4$	<i>o</i> ( <i>p</i> )-Acetoxynitrobenzene (637)
$C_7H_{12}O_6$	Quinic acid: v. p. 360	$C_8H_7N_3O$	Anisole- <i>anti</i> ( <i>syn</i> )-diazonium cyanide (147); H <sub>2</sub> O + HCN (247)
$C_7H_{13}BrN_2O_2$	Adaline: v. p. 360	$C_8H_7N_3O_6$	3, 4, 5(6)-Trinitro- <i>o</i> -xylene: EtOH (43)
$C_7H_{13}NO_2$	Piperidylacetic acid (395, † 398†); Cu salt: EtOH (391)	$C_8H_7N_3O_6$	3, 5-Dinitro-4-aminophenyl acetate: EtOH (+KOH) (454)
$C_7H_{13}NO_2$	$\alpha$ , $\alpha$ -Methylnitrocyclohexane: EtOH (664)	$C_8H_7N_3O_6$	3, 5-Dinitro-4-acetylaminophenol: EtOH (454)
$C_7H_{13}N_3O$	$\alpha$ , $\beta$ -Mesityl semicarbazone (656)		
$C_7H_{14}$	Methylcyclohexane: EtOH (664)		
$C_7H_{14}O$	Methyl amyl ketone (176)		
$C_7H_{14}O$	Dipropyl ketone (59, † 62, † 176, 294, 545†)		
$C_7H_{14}O$	Diisopropyl ketone (294, 545†)		
$C_7H_{14}O$	Ethyl isobutyl ketone (176, 545†)		



Formula	Name, solvents and literature	Formula	Name, solvents and literature
<b>Ultra-violet and Visible.—(Continued)</b>			
$C_8H_8$	Styrene: EtOH (25, 383, 384, 386, 393, 423, 619)	$C_8H_9NO_2$	Phenylaminoacetic acid and K salt: EtOH (386)
$C_8H_8BrN_3O_2$	5-Bromo-4-hydroxy- <i>m</i> -tolueneazoformamide: EtOH (+NaOH) (293)	$C_8H_9NO_3$	<i>o</i> ( <i>m</i> , <i>p</i> )-Nitrophenetole: EtOH, ligroin (43)
$C_8H_8ClNO$	Acetylchloroaminobenzene: H <sub>2</sub> O (497.5)	$C_8H_9NO_3$	Nitro- <i>p</i> -cresetole: EtOH (43)
$C_8H_8ClNO$	Chloroacetanilide: EtOH (199)	$C_8H_9NO_4$	Nitroquinol dimethyl ether: H <sub>2</sub> O, hexane (254); EtOH (32, 43); aniline, pyridine, ligroin, C <sub>6</sub> H <sub>6</sub> (43); CHCl <sub>3</sub> (43, 254); H <sub>2</sub> SO <sub>4</sub> (32)
$C_8H_8ClNO$	<i>p</i> -Chloroacetanilide (497.5)	$C_8H_9NO_4$	Hematinic acid imide: Et <sub>2</sub> O (171†); cf. p. 360
$C_8H_8N_2O_2$	Nitrosoacetanilide: Et <sub>2</sub> O (247)	$C_8H_9NO_4$	Ethyl citrazinate: EtOH (+NaOEt) (14)
$C_8H_8N_2O_2$	<i>p</i> -Nitrobenzaldoxime methyl ether (four forms): EtOH (80)	$C_8H_9NS$	Thioacetanilide and Na salt (445)
$C_8H_8N_2O_4$	3, 4(5)-Dinitro- <i>o</i> -xylene: EtOH (43)	$C_8H_9N_3O_2$	4-Hydroxy- <i>m</i> -tolueneazoformamide: EtOH (+NaOH) (293)
$C_8H_8N_2O_4$	4, 5-Dinitro- <i>o</i> -xylene: EtOH (43)	$C_8H_9N_3O_3$	2-Nitro-4-acetyl- <i>p</i> -phenylenediamine: EtOH (477)
$C_8H_8N_2O_5$	2, 4-Dinitrophenetole: H <sub>2</sub> O (86)	$C_8H_9N_3O_4$	3, 4-Dinitro-5-amino- <i>o</i> -xylene: EtOH (472)
$C_8H_8N_4O_5$	2, 5-Dinitro- <i>p</i> -tolylmethylnitrosoamine: EtOH (471, 472)	$C_8H_9N_3O_4$	3, 5-Dinitro-4(6)-amino- <i>o</i> -xylene (477); EtOH (472)
$C_8H_8N_4O_6$	3, 5-Dinitro- <i>p</i> -tolylmethylnitroamine: EtOH (471, 472)	$C_8H_9N_3O_4$	4(6), 5-Dinitro-3-amino- <i>o</i> -xylene: EtOH (472)
$C_8H_8N_6O_6$	Murexide: H <sub>2</sub> O (269, † 402)	$C_8H_9N_3O_4$	2, 4-Dinitrodimethylaniline: EtOH (218, 477)
$C_8H_8O$	Acetophenone (37, † 66, † 540, 636, 637, 642); EtOH (20); CHCl <sub>3</sub> (392)	$C_8H_9N_3O_4$	3, 4-Dinitrodimethylaniline: EtOH (218)
$C_8H_8O$	<i>o</i> ( <i>m</i> , <i>p</i> )-Toluic aldehyde: EtOH, Vap. (523)	$C_8H_9N_3O_4$	2, 3-Dinitromethyl- <i>p</i> -toluidine: EtOH (471)
$C_8H_8O_2$	Methyl benzoate: EtOH (119)	$C_8H_9N_3O_4$	3, 5-Dinitromethyl- <i>p</i> -toluidine (472)
$C_8H_8O_2$	Phenyl acetate (76, 636†)	$C_8H_{10}$	<i>o</i> ( <i>m</i> , <i>p</i> )-Xylene (37†); EtOH (27, 133, 263, † 379, 486); hexane (353†); Vap. (202, † 271, 469, 486); cf. p. 360
$C_8H_8O_2$	Phenylacetic acid (20, 37, † 527); H <sub>2</sub> O (659†); cf. p. 360; Na salt: EtOH + NaOH (317, 386); H <sub>2</sub> O (386, 659†)	$C_8H_{10}$	Ethylbenzene (20, 386, 423); EtOH (286, 486, † 619, 651†); Vap. (202, 271, 486, 651)
$C_8H_8O_2$	<i>o</i> ( <i>m</i> , <i>p</i> )-Toluic acid (487, 527)	$C_8H_{10}$	Dimethylfulvene: Vap. (602)
$C_8H_8O_2$	<i>ψ</i> , <i>m</i> -Toluic acid (487)	$C_8H_{10}BrClO_2$	4-Bromo-4-chloro-1, 1-dimethylcyclohexan-3, 5-dione: EtOH (199)
$C_8H_8O_2$	<i>p</i> -Xyloquinone (36); EtOH (409, 410); Vap. (531)	$C_8H_{10}Br_2O_2$	Dibromothymoquinone: EtOH (610); Vap. (531)
$C_8H_8O_2$	<i>o</i> -Methoxybenzaldehyde (636, † 637); EtOH (634, 636); EtOH + HCl (636†)	$C_8H_{10}Br_2O_2$	4-Dibromo-1, 1-dimethylcyclohexan-3, 5-dione: EtOH (199)
$C_8H_8O_2$	<i>m</i> -Methoxybenzaldehyde: EtOH (+HCl) (636†)	$C_8H_{10}ClN$	$\alpha$ -Chlorocollidine (504, 535†)
$C_8H_8O_2$	<i>p</i> -Methoxybenzaldehyde: EtOH (523, 634, 636†); (+HCl) (636†)	$C_8H_{10}Cl_2O_2$	4-Dichloro-1, 1-dimethylcyclohexan-3, 5-dione: EtOH (199)
$C_8H_8O_3$	Mandelic acid (527); EtOH (386)	$C_8H_{10}N_2$	Acetaldehyde phenylhydrazone: EtOH (40, 620); AcOH (40)
$C_8H_8O_3$	Piperonyl alcohol: EtOH, Vap. (533)	$C_8H_{10}N_2$	Benzeneazoethane: EtOH (247, 620, 621)
$C_8H_8O_3$	Vanillin: EtOH (523, 606†); H <sub>2</sub> O, Et <sub>2</sub> O (606†); hexane (604, † 606†); Vap. (523); cf. p. 360	$C_8H_{10}N_2O$	Nitrosodimethylaniline: EtOH (268)
$C_8H_8O_3$	Methyl <i>o</i> -hydroxybenzoate: EtOH (386)	$C_8H_{10}N_2O_2$	3-Nitromethyl- <i>p</i> -toluidine: EtOH (43, 472)
$C_8H_8O_3$	<i>o</i> ( <i>p</i> )-Methoxybenzoic acid and Na salts: EtOH (386)	$C_8H_{10}N_2O_2$	5(6)-Nitro-4-amino- <i>m</i> -xylene: EtOH (477)
$C_8H_8O_3$	Phenoxyacetic acid: EtOH (+NaOEt) (386†)	$C_8H_{10}N_2O_2$	<i>m</i> ( <i>p</i> )-Nitrodimethylaniline: EtOH (43)
$C_8H_8O_4$	Dehydracetic acid: EtOH (+NaOEt) (21)	$C_8H_{10}N_4O_2$	Caffeine (129†); H <sub>2</sub> O (264, 269†); cf. p. 360
$C_8H_8O_4$	Isodehydracetic acid: EtOH (21)	$C_8H_{10}O$	<i>o</i> ( <i>m</i> )-Cresol methyl ether: EtOH (27)
$C_8H_8O_4$	Dimethylpyronecarboxylic acid: EtOH (21)	$C_8H_{10}O$	Phenetole (20); EtOH (27, 526); Vap. (526)
$C_8H_8O_5$	Hematinic acid anhydride (481†); Et <sub>2</sub> O (171†); cf. p. 360	$C_8H_{10}O$	<i>m</i> , 4-Xylenol: EtOH (+NaOEt) (385, 533); Vap. (533)
$C_8H_8BrN_2$	Acetaldehyde <i>p</i> -bromophenylhydrazone: EtOH (40)	$C_8H_{10}O$	<i>p</i> -Xylenol: EtOH (+NaOEt) (385)
$C_8H_8BrO$	<i>p</i> -Bromophenetole: Vap. (526)	$C_8H_{10}O_2$	4-Hydroxy-3-methoxytoluene (137)
$C_8H_8FO$	<i>p</i> -Fluorophenetole: EtOH, Vap. (526)	$C_8H_{10}O_2$	Quinol dimethyl ether (32); EtOH (27, 638); H <sub>2</sub> SO <sub>4</sub> (27)
$C_8H_8NO$	Acetanilide (199, 641); EtOH (43, 119)	$C_8H_{10}O_2$	Resorcinol dimethyl ether (27, † 636); EtOH, H <sub>2</sub> SO <sub>4</sub> (32)
$C_8H_8NO$	Acetophenoneoxime: EtOH (119)	$C_8H_{10}O_2$	<i>o</i> -Dimethoxybenzene (Veratrole) (27†); hexane (604, † 606†); cf. p. 360
$C_8H_8NO$	<i>o</i> ( <i>p</i> )-Aminoacetophenone: EtOH (+HCl) (30)	$C_8H_{10}O_3$	Triacetic lactone ethyl ether: EtOH (21)
$C_8H_8NO$	Benz- <i>anti</i> -aldoxime <i>N</i> ( <i>O</i> )-methyl ether: EtOH (80)	$C_8H_{10}O_4$	Diethyl acetylenedicarboxylate (58†)
$C_8H_8NO_2$	Methylantranilic acid: EtOH (395)	$C_8H_{11}BrO_2$	4-Bromo-1, 1-dimethylcyclohexan-3, 5-dione: EtOH (199)
$C_8H_8NO_2$	Anilinoacetic acid: EtOH (391); Cu, Na salts: H <sub>2</sub> O (391)	$C_8H_{11}ClO_2$	4-Chloro-1, 1-dimethylcyclohexan-3, 5-dione: EtOH, NaOEt (199)
$C_8H_8NO_2$	3(4)-Nitro- <i>o</i> -xylene: EtOH, ligroin (43)		



Formula	Name, solvents and literature	Formula	Name, solvents and literature
<b>Ultra-violet and Visible.—(Continued)</b>			
$C_8H_{11}ClO_5$	Trimethylpyroxonium perchlorate: $H_2SO_4$ (241)	$C_9H_5BrN_2O_3$	<i>p</i> -Bromophenyloximidooxazolone: $Et_2O$ (243); metallic salts: $CHCl_3$ , $C_6H_5N$ , $PhOH$ (243); Ba, Cs, K, Li, Na, $NH_4$ , Rb salts: $EtOAc$ + $Me_2CO$ (243)
$C_8H_{11}ClO_5S$	Dimethyl-2, 6-mercapto-4-pyroxonium perchlorate: $H_2SO_4$ (241)	$C_9H_5Br_2NO$	5, 7-Dibromo-8-hydroxyquinoline: $EtOH$ (+ $NaOH$ ) (158)
$C_8H_{11}ClO_6$	Methoxy-4-dimethyl-2, 6-pyroxonium perchlorate: $H_2SO_4$ (241)	$C_9H_5N_3O_{10}$	Trinitrophenylmalonic acid, K salt: $H_2O$ , $EtOH$ (249)
$C_8H_{11}ClO_6$	Dimethylmethoxypyroxonium perchlorate: $H_2SO_4$ (242)	$C_9H_6O_2$	Phenylpropionic acid (423, 527); $EtOH$ (386, 607, 619)
$C_8H_{11}IO_2$	Dimethylmethoxypyroxonium iodide: $H_2O$ , $CHCl_3$ (242)	$C_9H_7ClN_2$	3-Phenyl-5-chloropyrazole (554)
$C_8H_{11}N$	3- <i>o</i> -Xylidine: P, $EtOH$ , Vap. (510)	$C_9H_7ClN_2O$	1-Phenyl-3-chloropyrazolone (554)
$C_8H_{11}N$	2- <i>m</i> -Xylidine: P, $EtOH$ , Vap. (510)	$C_9H_7N$	Quinoline (650†); P (509†); $EtOH$ (143, 262, 263, † 386, 509†); $HCl$ (143, 223, 386); $CHCl_3$ , $HI$ (223); Vap. (509†); cf. p. 360
$C_8H_{11}N$	4- <i>m</i> -Xylidine (507)	$C_9H_7N$	Isoquinoline: $EtOH$ (386, 606†); $Et_2O$ (606†); $EtOH$ + $HCl$ (386); hexane (156, † 603, † 606†); cf. p. 360
$C_8H_{11}N$	Collidine (504, 535); Vap. (508)	$C_9H_7NO$	$\alpha$ -Hydroxyquinoline (479†); $EtOH$ (275)
$C_8H_{11}N$	Ethylaniline (37†); P, $EtOH$ , Vap. (510)	$C_9H_7NO$	6-Hydroxyquinoline: $EtOH$ (135)
$C_8H_{11}N$	Dimethylaniline (386); P, Vap. (510); $EtOH$ (20, 384)	$C_9H_7NO$	8-Hydroxyquinoline: $EtOH$ (+ $NaOH$ ) (+ $HCl$ ) (158)
$C_8H_{11}NO$	<i>o</i> ( <i>p</i> )-Phenetidine: $EtOH$ , Vap. (526)	$C_9H_7NO$	$\beta$ -Indole aldehyde (648)
$C_8H_{11}NO$	<i>m</i> -Dimethylaminophenol: $EtOH$ , Vap. (519)	$C_9H_7NO_2$	$\beta$ -Indolecarboxylic acid (648)
$C_8H_{11}NO_3$	Isonitrosodimethyldihydroresorcinol, and Na salt: $EtOH$ (400)	$C_9H_7NO_2$	Methyl <i>o</i> -cyanobenzoate: $Et_2O$ (576)
$C_8H_{12}ClN$	Dimethylaniline hydrochloride: $EtOH$ (384)	$C_9H_7NO_2$	Methylisophthalimide: $Et_2O$ (576)
$C_8H_{12}ClN$	Collidine hydrochloride (504)	$C_9H_7NO_2$	Methylisatin and $\psi$ form: $EtOH$ (275)
$C_8H_{12}N_2O_3$	Veronal: v. p. 360	$C_9H_7NO_2$	$\alpha$ -Hydroxy- $\beta$ -indole aldehyde (648†)
$C_8H_{12}N_4$	Azoisobutyronitrile (247)	$C_9H_7NO_4$	<i>o</i> ( <i>m</i> , <i>p</i> )-Nitrocinnamic acid (527)
$C_8H_{12}O_2$	Dimethyldihydroresorcinol: $EtOH$ (+ alk.) (27)	$C_9H_8ClN$	Quinoline hydrochloride: $EtOH$ (263†)
$C_8H_{12}O_2$	1, 1-Dimethylcyclohexan-3, 5-dione (176); $EtOH$ (+ $NaOEt$ ) (199)	$C_9H_8Cl_2N_2$	3-Phenyl-5-chloropyrazole hydrochloride (554)
$C_8H_{12}O_3$	Ethyl $\beta$ -acetylcrotonate: $H_2O$ , hexane (204†)	$C_9H_8N_2$	1-Phenylpyrazole (554)
$C_8H_{12}O_4$	Ethyl acetoacetylacetate: $EtOH$ (+ $NaOEt$ ) (21)	$C_9H_8N_2O$	1-Phenyl-3, 5-pyrazolone (554); $NaOEt$ (554)
$C_8H_{12}O_5$	Ethyl oxaloacetate: $EtOH$ (+ alk.) (23†); hexane, $NaOH$ (370, † 371†); Na salt: $H_2O$ + $Na_2CO_3$ , $CHCl_3$ (237)	$C_9H_8N_2O$	1(3)-Phenyl-5-pyrazolone (554)
$C_8H_{13}NO$	Tropinone: v. p. 360	$C_9H_8N_2O_2$	<i>N</i> -Methyl- <i>p</i> -nitrobenzyl cyanide: $MeOH$ (405)
$C_8H_{13}NO_2$	Aminodimethyldihydroresorcinol: $EtOH$ (27)	$C_9H_8N_4O_8$	2, 3, 5-Trinitroacetylaminanisole: $EtOH$ (453)
$C_8H_{13}NO_6$	Diethyl nitroisuccinate: $EtOH$ (198)	$C_9H_8N_4O_8$	2, 3, 6-Trinitroacetylaminanisole: $EtOH$ $NaOH$ (453)
$C_8H_{13}NO_6$	Diethyl nitromethylmalonate: $EtOH$ , $CHCl_3$ (255)	$C_9H_8O$	Cinnamic aldehyde: $EtOH$ , Vap. (523)
$C_8H_{14}Br_2O_3$	Ethyl $\beta$ -ethoxycrotonate dibromide: $EtOH$ (235)	$C_9H_8O_2$	Allocinnamic acid: $EtOH$ (619)
$C_8H_{14}O$	Methylheptenone (66, † 67, † 176, 294); cf. p. 360	$C_9H_8O_2$	Cinnamic acid: $H_2O$ (35, 182, † 613, 614, 659†); $EtOH$ (35, 119, 383, 384, 385, 386, 393, 423, 527, 607, 613, 614, 617, 619); $NaOEt$ , $HCl$ (35); $C_6H_6$ (494†); cf. p. 360; Na salt (182†); $H_2O$ (659†)
$C_8H_{14}O$	Dipropylketene: hexane (370, † 371†)	$C_9H_8O_2$	Atropic acid: $EtOH$ (119)
$C_8H_{14}O_2S_2$	Dipropyl dithiooxalate: $EtOH$ (536)	$C_9H_8O_3$	<i>o</i> -Coumaric acid: $EtOH$ (43, 385); (+ $NaOEt$ ) (43); Na salt: $EtOH$ + $NaOEt$ (43)
$C_8H_{14}O_2S_2$	Diethyl dithiosuccinate: $EtOH$ (536†)	$C_9H_8O_3$	<i>m</i> -Coumaric acid: $EtOH$ (385)
$C_8H_{14}O_3$	Ethyl ethylacetoacetate (59, † 68†): $EtOH$ (22, 59†)	$C_9H_8O_3$	<i>p</i> -Coumaric acid: $EtOH$ (385)
$C_8H_{14}O_3$	Ethyl $\beta$ -ethoxycrotonate (22, 228, 255†); $H_2O$ , hexane, $NaOEt$ (220); $EtOH$ (220, 226, 235, 385); cf. p. 360	$C_9H_8O_3$	<i>o</i> ( <i>m</i> , <i>p</i> )-Acetoxybenzaldehyde (636, 637)
$C_8H_{14}O_3$	Ethyl dimethylacetoacetate (228); $EtOH$ (220, 226, 235); hexane (220)	$C_9H_9N$	$\alpha$ ( $\beta$ )-Methylindole: hexane (171†)
$C_8H_{15}NO$	Tropine: v. p. 360	$C_9H_9NO_2$	<i>N</i> ( <i>O</i> )-Ethyl- <i>o</i> -oxycarbanil (283, 479†)
$C_8H_{16}O$	Methyl hexyl ketone (59, † 62, † 294, 545†); $EtOH$ (609)	$C_9H_9NO_3$	Hippuric acid: $H_2O$ (286, 594, † 659†); cf. p. 360; Na salt: $H_2O$ (659†)
$C_8H_{16}O$	Pentamethylacetone (294)	$C_9H_9NO_4$	<i>o</i> -Carbamylphenoxyacetic acid: $EtOH$ (456)
$C_8H_{17}N$	Coniine: P, $EtOH$ , Vap. (509)	$C_9H_9NO_4$	Dimethyl quinolinate: $Et_2O$ (578)
$C_8H_{18}$	Octane (286†)	$C_9H_9N_3O$	$\alpha$ ( $\beta$ )-4-Acetyl-3, 4-tolylenediazoimide: $EtOH$ (474)
$C_8H_{18}O$	<i>n</i> -Octyl alcohol (438†)	$C_9H_9N_3O_3$	Acetyl- <i>p</i> -benzoquinone semicarbazone (293)
$C_8H_{18}O$	Isooctyl alcohol (261†)	$C_9H_{10}$	$\alpha$ ( $\beta$ )-Methylstyrene: $EtOH$ (384)
$C_8H_{20}IP$	Tetraethylphosphonium iodide: $H_2O$ , $EtOH$ , $CHCl_3$ , amyl alcohol (242)	$C_9H_{10}N_2O$	Pyruvaldehyde phenylhydrazone: $EtOH$ , $NaOEt$ (45)
		$C_9H_{10}N_4O_3$	Nitroaceto- <i>p</i> -toluidine: $EtOH$ (43)



Formula	Name, solvents and literature	Formula	Name, solvents and literature
<b>Ultra-violet and Visible.—(Continued)</b>			
$C_9H_{10}N_4O_6$	2, 3, 6-Trinitrodimethyl- <i>p</i> -toluidine: EtOH (471)	$C_9H_{11}IN$	Phenyltrimethylammonium iodide: EtOH (395)
$C_9H_{10}O$	Phenyl ethyl ketone (20)	$C_9H_{11}N_2O_2$	Ethyl 1-amino-2, 5-dimethyl-4-pyrrolicarboxylate (362)
$C_9H_{10}O_2$	$\beta$ -Phenylpropionic acid: EtOH (20, 37, † 386, 423, 607, 619); $H_2O$ (659†); cf. p. 360; Na salt: $H_2O$ (659†)	$C_9H_{14}O$	Phorone (14, 66, † 67, † 70, † 176, 411); EtOH (404, 406, 410, 573†); $H_2O$ , hexane, AcOH (573†); $H_2SO_4$ (406, 573†); $CHCl_3$ , $ZnCl_2$ (406); Vap. (539†); cf. p. 360
$C_9H_{10}O_2$	Benzyl acetate (20†)	$C_9H_{14}O_6$	Diethyl acetonedicarboxylate (58†, 176); EtOH (+alk.) (23†)
$C_9H_{10}O_2$	Ethyl benzoate (37†)	$C_9H_{14}O_6$	Diethyl hydroxymethylenesuccinate: EtOH (22)
$C_9H_{10}O_3$	Tropic acid: EtOH (136); cf. p. 360	$C_9H_{15}BrO_4$	Dipropyl bromomalonate (198)
$C_9H_{10}O_3$	Ethyl <i>o</i> -hydroxybenzoate and Na salt: EtOH (385)	$C_9H_{15}NO_3$	Ecgonine: v. p. 360
$C_9H_{10}O_4$	Veratric acid: EtOH (140, 287)	$C_9H_{15}N_3O_3$	Triethyl isocyanurate (120); EtOH (280)
$C_9H_{11}BrN_2$	Acetone <i>p</i> -bromophenylhydrazone: EtOH (40)	$C_9H_{15}N_3O_3$	Triethyl cyanurate (120)
$C_9H_{11}IN_2$	Dimethylbenziminazolium iodide: $H_2O$ (631)	$C_9H_{16}$	Geraniolene: Vap. (602)
$C_9H_{11}N$	Tetrahydroquinoline: EtOH (263†)	$C_9H_{17}NO_2$	Ethyl piperidoacetate (395†)
$C_9H_{11}NO$	8-Hydroxytetrahydroquinoline: EtOH (+HCl) (158)	$C_9H_{18}N_6$	Triethyl(iso)melamine: EtOH (280)
$C_9H_{11}NO$	Methylacetanilide: EtOH (43)	$C_9H_{18}O$	Hexamethylacetone (294, 545†); P, $H_2O$ , EtOH, heptane, $CHCl_3$ (546†)
$C_9H_{11}NO$	<i>p</i> -Dimethylaminobenzaldehyde: EtOH (30, 519); HCl (30); Vap. (519)	$C_9H_{19}NO_2$	<i>d</i> - $\gamma$ -Nonyl nitrite: P (490†)
$C_9H_{11}NO_2$	Phenylalanine: v. p. 360	$C_9H_{21}N$	Tripropylamine (63†)
$C_9H_{11}NO_2$	Dimethylantranilic acid: EtOH (395)	$C_{10}H_6Cl_2$	Dichloronaphthalene (10 isomers): hexane, Vap. (372.3)
$C_9H_{11}NO_2$	Methyl methylantranilate: EtOH (395)	$C_{10}H_6N_2O_4$	Quinoxalindicarboxylic acid and Fe, Na salts: $H_2O$ (394)
$C_9H_{11}NO_2$	Methyl anilinoacetate (386†)	$C_{10}H_6O_2$	$\alpha$ -Naphthoquinone (36, 410, 432†); EtOH (409, 518); Vap. (531); $\beta$ -Naphthoquinone (409); EtOH, Vap. (518)
$C_9H_{11}NO_2$	Nitromesitylene: EtOH (43)	$C_{10}H_6O_3$	Hydroxymethyleneindandione: $H_2O$ (+HCl) (401); Na salt (401)
$C_9H_{11}NO_3$	Tyrosine (594†); $H_2O$ (286); cf. p. 360	$C_{10}H_6O_4$	Phthalyl acetic acid: AcOH, $H_2SO_4$ (500)
$C_9H_{11}NS$	<i>N</i> -Methylthioacetanilide (445)	$C_{10}H_7Br$	$\alpha(\beta)$ -Bromonaphthalene: EtOH, Vap. (518); cf. p. 360
$C_9H_{11}N_3O_2$	Phenetoleazoformamide: EtOH (293)	$C_{10}H_7BrN_2O_3$	<i>p</i> -Bromophenyloximidoxazolone methyl ether: Et <sub>2</sub> O (243)
$C_9H_{11}N_3O_2$	Acetone <i>p</i> -nitrophenylhydrazone: EtOH (40)	$C_{10}H_7Cl$	$\alpha(\beta)$ -Chloronaphthalene: EtOH, Vap. (518)
$C_9H_{11}N_3O_4$	2, 5-Dinitrodimethyl- <i>p</i> -toluidine: EtOH (471)	$C_{10}H_7ClN_2$	$\alpha$ -Naphthalenediazonium chloride: $H_2O$ , dil. acid (89, 247)
$C_9H_{11}N_3O_4$	2, 6 (and 3, 5)-Dinitrodimethyl- <i>p</i> -toluidine: EtOH (471, 472)	$C_{10}H_7NO_2$	$\alpha(\beta)$ -Nitronaphthalene: EtOH (43, 518); ligroin, $C_6H_6$ (43)
$C_9H_{11}N_3O_4$	3, 5-Dinitro-4(6)-methylamino- <i>o</i> -xylene: EtOH (477)	$C_{10}H_7NO_2$	Cinchoninic acid: v. p. 360
$C_9H_{12}$	Mesitylene (37†); Vap. (271)	$C_{10}H_7NO_3$	Acetylisin: EtOH (435†)
$C_9H_{12}$	Propylbenzene (20†, 386†)	$C_{10}H_8$	Naphthalene (42, 133, 324); EtOH (18, † 261, † 263, † 379, 386, † 431, 518, 599, 606†); hexane (156, † 306, † 372, † 606†); Et <sub>2</sub> O (606†); Vap. (304, 305, 372, 518, 599); cf. p. 360
$C_9H_{12}ClN$	Tetrahydroquinoline hydrochloride: EtOH (263†)	$C_{10}H_8N_2$	2-Dipyridyl: EtOH, Vap. (263, † 520)
$C_9H_{12}ClNO_2$	Phenylalanine hydrochloride: EtOH (649†)	$C_{10}H_8N_2O_2$	$\alpha$ -Nitro- $\beta$ -naphthylamine: EtOH (518)
$C_9H_{12}ClNO_3$	Tyrosine hydrochloride: EtOH (649†)	$C_{10}H_8N_4O_6$	4-Nitro-1, <i>p</i> -nitrophenyl-3-methyl-5-pyrazolone (554)
$C_9H_{12}N_2$	Acetaldehyde phenylmethylhydrazone: EtOH (40)	$C_{10}H_8O$	$\alpha(\beta)$ -Naphthol: EtOH (360, 432, † 518); cf. p. 360
$C_9H_{12}N_2$	Propionaldehyde phenylhydrazone: EtOH + AcOH (40)	$C_{10}H_8O_4$	Benzylidenemalononic acid: $H_2O$ , EtOH (+NaO-Et) (35)
$C_9H_{12}N_2O$	Acetone phenylhydrazone: EtOH, AcOH (40)	$C_{10}H_9BrN_2O$	1, <i>p</i> -Bromophenyl-5-methyl-3-pyrazolone (554)
$C_9H_{12}N_2O_2$	Dimethylbenziminazolol: EtOH (631)	$C_{10}H_9ClN_2$	1-Phenyl-3-methyl-5-chloropyrazole (554)
$C_9H_{12}N_2O_2$	2-Nitrodimethyl- <i>p</i> -toluidine: EtOH (471)	$C_{10}H_9N$	$\alpha$ -Naphthylamine: EtOH (518); cf. p. 360
$C_9H_{12}N_2O_2$	3-Nitrodimethyl- <i>p</i> -toluidine: EtOH (43, 471)	$C_{10}H_9N$	$\beta$ -Naphthylamine: EtOH (478, 518); cf. p. 360
$C_9H_{12}N_2O_4S$	$\gamma$ -Cumenediazonium sulfate: $H_2O$ (247)	$C_{10}H_9NO$	<i>p</i> -Methoxyquinoline: v. p. 360
$C_9H_{12}O$	Benzyl ethyl ether (37†); EtOH (80); Vap. (624)	$C_{10}H_9NO$	6-Methoxyquinoline: EtOH (135)
$C_9H_{12}O_2$	Tetramethylpyrone (21†)	$C_{10}H_9NO$	Carbostyryl <i>N</i> ( <i>O</i> )-methyl ether (275); EtOH (479†)
$C_9H_{12}O_3$	Phloroglucinol trimethyl ether: EtOH (281)		
$C_9H_{13}N$	Mesidine: P, EtOH, Vap. (510)		
$C_9H_{13}N$	Dimethyl- <i>o</i> -toluidine: EtOH (384, 386)		
$C_9H_{13}NO$	$\gamma$ -Ethoxylutidine (14)		
$C_9H_{13}NO_2$	Ethyl dimethylpyrrolicarboxylate (363, 364)		
$C_9H_{13}NO_3$	Adrenaline (128†)		
$C_9H_{13}ClN$	Phenyltrimethylammonium chloride: EtOH (395)		
$C_9H_{14}ClN$	Dimethyl- <i>o</i> -toluidine hydrochloride: EtOH (384)		



Formula	Name, solvents and literature	Formula	Name, solvents and literature
Ultra-violet and Visible.—(Continued)			
$C_{10}H_9N_3O_2$	Isonitrosophenylmethylpyrazolone: EtOH (+NaOEt) (402)	$C_{10}H_{13}N_3O_4$	Diethyl-2(3), 4-dinitroaniline: EtOH (218)
$C_{10}H_9N_3O_3$	1- <i>m</i> -Nitrophenyl-5-methyl-5-pyrazolone (554)	$C_{10}H_{14}$	Cymene: EtOH, Vap. (271)
$C_{10}H_{10}$	1, 4-Dihydronaphthalene (42); EtOH (379)	$C_{10}H_{14}$	<i>m</i> -Cymene: EtOH (225)
$C_{10}H_{10}Br_2O_2$	Dibromothymoquinone: EtOH (610); Vap. (531)	$C_{10}H_{14}$	<i>tert</i> -Butylbenzene (20, † 37 †)
$C_{10}H_{10}ClN$	Quinoline methochloride: H <sub>2</sub> O, EtOH (223)	$C_{10}H_{14}BrClO$	$\alpha$ , $\alpha'$ -Chlorobromocamphor: EtOH (412)
$C_{10}H_{10}ClN$	$\alpha(\beta)$ -Naphthylamine hydrochloride: EtOH (518)	$C_{10}H_{14}Br_2O$	$\alpha$ , $\alpha'(\beta)$ -Dibromocamphor: EtOH (412)
$C_{10}H_{10}ClNO$	6-Methoxyquinoline hydrochloride (135)	$C_{10}H_{14}BrNO_3$	$\alpha$ , $\alpha'$ -Bromonitrocarnphor: EtOH (412)
$C_{10}H_{10}Cl_2O_2$	Dichlorothymoquinone: EtOH (610); Vap. (531)	$C_{10}H_{14}BrNO_3$	$\beta(\pi)$ -Bromonitrocarnphor: EtOH, Et <sub>2</sub> O, C <sub>2</sub> H <sub>4</sub> Cl <sub>2</sub> (412); Na salt: EtOH (412)
$C_{10}H_{10}IN$	Quinoline methiodide: EtOH, CHCl <sub>3</sub> (223)	$C_{10}H_{14}ClNO_3$	$\alpha$ , $\alpha'$ -Chloronitrocarnphor: EtOH (412)
$C_{10}H_{10}IN$	Isoquinoline methiodide: EtOH (631); CHCl <sub>3</sub> (223)	$C_{10}H_{14}Cl_2O_2$	Camphoryl chloride, <i>cis</i> and <i>cis-trans</i> : Et <sub>2</sub> O (578)
$C_{10}H_{10}N_2O$	1-Phenyl-3(5)-methyl-5(3)-pyrazolone (554)	$C_{10}H_{14}N_2$	Acetone phenylmethylhydrazone: EtOH (40)
$C_{10}H_{10}O$	Benzylideneacetone: H <sub>2</sub> O (534); EtOH (13, 35); H <sub>2</sub> SO <sub>4</sub> (13)	$C_{10}H_{14}N_2$	Propionaldehyde phenylmethylhydrazone: EtOH (40)
$C_{10}H_{10}O_2$	Benzoylacetone: EtOH (23, † 475, 478); alk. (23 †); Al salts: EtOH, alk. (23 †); V salts: EtOH (475)	$C_{10}H_{14}N_2$	Nicotine: P, Vap. (509); EtOH (136, 264, 509)
$C_{10}H_{10}O_2$	<i>o(m, p)</i> -Diacetylbenzene: EtOH, CHCl <sub>3</sub> , hexane (642)	$C_{10}H_{14}N_4O_3$	Ethoxycaffeine: EtOH (269)
$C_{10}H_{10}O_2$	(Iso)Safrole: EtOH (119)	$C_{10}H_{14}O$	Carvocol: EtOH, Vap. † (533)
$C_{10}H_{10}O_2$	$\alpha$ -Methylcinnamic acid: EtOH (384, 393)	$C_{10}H_{14}O$	Carvone (294); Vap. (532)
$C_{10}H_{10}O_2$	$\beta$ -Methylcinnamic acid: EtOH (384)	$C_{10}H_{14}O$	Thymol: H <sub>2</sub> O (286); EtOH (385, 533); EtOH + NaOEt (660 †); Vap. (533); Na salt (660 †)
$C_{10}H_{10}O_3$	Methyl coumarate: EtOH, NaOEt (385)	$C_{10}H_{14}O_2$	Camphorquinone (416 †); EtOH (415, 609); C <sub>6</sub> H <sub>6</sub> (415); toluene (644 †); Vap. (532)
$C_{10}H_{10}O_4$	Meconin: EtOH, Et <sub>2</sub> O (606 †)	$C_{10}H_{14}O_3$	Camphoric anhydride: Vap. (532)
$C_{10}H_{10}O_4$	Dimethyl terephthalate (284)	$C_{10}H_{14}O_4$	Tetraacetylene: EtOH (+NaOEt) (21)
$C_{10}H_{10}O_5$	Opianic acid: EtOH, Et <sub>2</sub> O (603, † 605, † 606 †)	$C_{10}H_{16}BrO$	$\alpha$ -Bromocamphor: EtOH (412, 413)
$C_{10}H_{10}O_6$	Dimethoxyterephthalic acid (236)	$C_{10}H_{16}BrO$	$\beta$ -Bromocamphor: EtOH (412)
$C_{10}H_{10}O_6$	Hemipinic acid: EtOH, Et <sub>2</sub> O (606 †)	$C_{10}H_{16}BrO_4S$	<i>d</i> - $\alpha$ -Bromocamphor- $\beta$ -sulfonic acid, NH <sub>4</sub> salt: EtOH (525)
$C_{10}H_{11}NO$	Benzylideneacetoxime (534)	$C_{10}H_{16}BrO_4S$	$\alpha$ -Bromocamphor- $\pi$ -sulfonic acid, NH <sub>4</sub> salt: EtOH (413)
$C_{10}H_{11}NO$	$\beta$ -Indoleethyl alcohol (648 †)	$C_{10}H_{16}ClO$	$\alpha$ -Chlorocamphor: H <sub>2</sub> O, EtOH (412, 413)
$C_{10}H_{11}NO_4$	Ethyl <i>p</i> -nitrophenylacetate: EtOH (+NaOH) (317)	$C_{10}H_{16}ClO_4S$	$\alpha$ -Chlorocamphor- $\beta$ -sulfonic acid, K salt: H <sub>2</sub> O, NaOH (413)
$C_{10}H_{11}N_3O_4$	Nitrodiaetylphenylenediamine: EtOH (477)	$C_{10}H_{16}N$	Diethylaniline: P, EtOH, Vap. (510)
$C_{10}H_{11}N_3O_7$	4(6), 5-Dinitro-3-acetylaminoveratrole: Neutral and alk. sol. (190)	$C_{10}H_{16}NO$	Carvoneoxime: EtOH (532)
$C_{10}H_{12}$	Dicyclopentadiene: Et <sub>2</sub> O, EtOH (618)	$C_{10}H_{16}NO_2$	Ethyl trimethylpyrrolecarboxylate (363, 364)
$C_{10}H_{12}$	1, 2, 3, 4-Tetrahydronaphthalene (42); EtOH (379); Vap. (518)	$C_{10}H_{16}NO_2$	Isonitrosocamphor: EtOH (+alk.) (31)
$C_{10}H_{12}$	1, 4, 6, 9-Tetrahydronaphthalene (42)	$C_{10}H_{16}NO_2S$	Camphor- $\beta$ -sulfonamhydramide: EtOH (413)
$C_{10}H_{12}N_2O$	Diacetylphenylhydrazone: EtOH, NaOEt (45)	$C_{10}H_{16}NO_3$	Nitrocarnphor: EtOH, Et <sub>2</sub> O, C <sub>2</sub> H <sub>4</sub> Cl <sub>2</sub> (412); Na salt: EtOH (412)
$C_{10}H_{12}N_2O$	Pyruvaldehyde phenylmethylhydrazone (45)	$C_{10}H_{16}N_3O_3$	Ethyl 2, 5-dimethyl-1-ureido-4-pyrrolecarboxylate (362)
$C_{10}H_{12}N_2O_3$	3-Nitromethylaceto- <i>p</i> -toluidide: EtOH (43)	$C_{10}H_{16}$	Bornylene: Vap. (602)
$C_{10}H_{12}O$	Anethole (122, 150 †)	$C_{10}H_{16}$	Camphene: Vap. (602)
$C_{10}H_{12}O$	Cumaldehyde: EtOH, Vap. (523)	$C_{10}H_{16}$	Dipentene (225)
$C_{10}H_{12}O$	$\alpha(\beta)$ -Ethoxystyrene: EtOH (383)	$C_{10}H_{16}$	Limonene (120); EtOH (225); Vap. (602)
$C_{10}H_{12}O$	Methylchavicol (150 †)	$C_{10}H_{16}$	$\alpha(\beta)$ -Phellandrene: EtOH (225); Vap. (602)
$C_{10}H_{12}O$	<i>ar</i> -Tetrahydro- $\alpha(\beta)$ -naphthol: EtOH (360)	$C_{10}H_{16}$	$\alpha$ -Pinene: EtOH (225); Vap. (602)
$C_{10}H_{12}O_2$	Eugenol and isoeugenol (150 †); EtOH (119, 533, 628 †); Vap. (533 †)	$C_{10}H_{16}$	Sylvestrene: EtOH (225); Vap. (602)
$C_{10}H_{12}O_2$	Ethyl phenylacetate (20, † 37 †)	$C_{10}H_{16}$	Terpinene (120)
$C_{10}H_{12}O_2$	Thymoquinone (36); Vap. (531)	$C_{10}H_{16}$	Terpinolene (120)
$C_{10}H_{12}O_3$	Ethyl phenoxyacetate (20)	$C_{10}H_{16}$	Turpentine (260 †)
$C_{10}H_{13}NO_2$	Methyl dimethylantranilate: EtOH (395)	$C_{10}H_{16}BrNO_3S$	$\alpha$ -Bromocamphor- $\pi$ -sulfonamide: EtOH (413)
$C_{10}H_{13}NO_2$	Ethyl anilinoacetate: EtOH (395)	$C_{10}H_{16}ClNO_3S$	$\alpha$ -Chlorocamphorsulfonamide: EtOH (413)
$C_{10}H_{13}NO_2$	<i>o</i> -Benzobetaine: EtOH (395)	$C_{10}H_{16}N_2O$	$\alpha(\beta)$ -Camphorquinonehydrazone (368)
$C_{10}H_{13}N_3O_4$	3, 5-Dinitro-4(6)-dimethylamino- <i>o</i> -xylene: EtOH (477)	$C_{10}H_{16}N_2O_2$	Methyl $\gamma$ -diazocamphonanate (349.5)
$C_{10}H_{13}N_3O_4$	3, 5-Dinitro-4(6)-ethylamino- <i>o</i> -xylene: EtOH (477)	$C_{10}H_{16}N_2O_3$	Ethyl 1-amino-2, 3, 5-trimethyl-4-pyrrolecarboxylate (362)
		$C_{10}H_{16}O$	Camphor (294, 416); EtOH (31, 261, † 270, 412, 415, † 525); Et <sub>2</sub> O, C <sub>2</sub> H <sub>4</sub> Cl <sub>2</sub> (412); cyclohexane (415 †); Vap. (532)
		$C_{10}H_{16}O$	Carvenone (120)



Formula	Name, solvents and literature	Formula	Name, solvents and literature
Ultra-violet and Visible.—(Continued)			
$C_{10}H_{16}O$	Citral (66,† 67†); EtOH (533, 539); Vap. (539); cf. p. 360	$C_{11}H_{12}N_2O$	1, <i>p</i> -Tolyl-3-methyl-5-pyrazolone (554)
$C_{10}H_{16}O$	Dihydrocarvone (120)	$C_{11}H_{12}N_2O_2$	Tryptophane: EtOH (648,† 649); cf. p. 360
$C_{10}H_{16}O$	Fenchone (294); Vap. (532)	$C_{11}H_{12}N_4O_6$	2, 4, 6-Trinitrophenylpiperidine: EtOH (477)
$C_{10}H_{16}O$	Pulegone (120); EtOH, Vap. (533)	$C_{11}H_{12}O_2$	$\alpha$ , $\beta$ -Dimethylcinnamic acid: EtOH (393)
$C_{10}H_{16}O_2$	Buccocamphor (447)	$C_{11}H_{12}O_2$	Ethyl cinnamate (37†); EtOH (35)
$C_{10}H_{16}O_4$	Camphoric acid: EtOH (261†); Na salt: $H_2O$ (578)	$C_{11}H_{12}O_2$	Anisalacetone: EtOH, $H_2SO_4$ (13)
$C_{10}H_{16}O_5$	Diethyl acetylsuccinate: EtOH (+alk.) (23†)	$C_{11}H_{12}O_2$	Ethyl <i>o</i> ( <i>m</i> )-coumarate: EtOH (+NaOEt) (385)
$C_{10}H_{16}O_5$	Diethyl ethoxyfumarate: EtOH (23,† 237); alk. (23†)	$C_{11}H_{12}O_2$	$\beta$ -Ethoxycinnamic acid: EtOH (383)
$C_{10}H_{16}O_5$	Diethyl dimethyloxalacetate: EtOH (237)	$C_{11}H_{12}O_2$	Ethyl benzoylacetate: EtOH (23); (+NaOEt) (23, 385); Al salts: EtOH (+NaOEt) (23); Na salt: EtOH (383)
$C_{10}H_{17}N$	Camphorimide: EtOH (532)	$C_{11}H_{12}O_4$	Diacetyldimethylpyrone; EtOH (+NaOEt) (21)
$C_{10}H_{17}NO$	Camphoroxime: EtOH (31, 525)	$C_{11}H_{12}O_6$	Diethyl chelidonate (21)
$C_{10}H_{17}NO_2$	Nitrocamphane: EtOH (+NaOH) (412)	$C_{11}H_{12}Br_2N_2O_2$	Dibromo-4-hydroxy-2-methyl-5-isopropylbenzeneazoformamide: EtOH (+NaOH) (293)
$C_{10}H_{17}NO_2S$	Camphor- $\beta$ -sulfonamide: EtOH (413)	$C_{11}H_{12}N$	Dimethyldihydroisoquinoline: EtOH (631)
$C_{10}H_{18}O$	<i>d</i> ( <i>l</i> )-Borneol: EtOH (225)	$C_{11}H_{12}N$	Corydaldine: $H_2O$ (140, 287)
$C_{10}H_{18}O$	Cineol: EtOH (225)	$C_{11}H_{12}NO_2$	Hydrohydrastinine: Et <sub>2</sub> O (145); hexane (606†)
$C_{10}H_{18}O$	Citronellal: EtOH (533)	$C_{11}H_{12}NO_2$	Hydrastinine: hexane (606†); EtOH (140, 287, 606†); $H_2O$ , Et <sub>2</sub> O (145, 606†)
$C_{10}H_{18}O$	<i>L</i> -Linalool: EtOH (533†)	$C_{11}H_{12}NO_4$	Ethyl $\alpha$ -carbamyphenoxycetate: EtOH (456)
$C_{10}H_{18}O$	Geraniol: EtOH (533†)	$C_{11}H_{12}N_2O_4$	2, 4-Dinitrophenylpiperidine: EtOH (477)
$C_{10}H_{18}O$	Menthone (294); EtOH (533)	$C_{11}H_{12}BrN_2O_2$	3-Bromo-4-hydroxy-2-methyl-5-isopropylbenzeneazoformamide: EtOH (+NaOH) (293)
$C_{10}H_{18}O_2$	Acetylmethyl hexyl ketone (176, 294)	$C_{11}H_{14}Br_2O_2$	Cyclohexanespiro-4, 4-dibromocyclohexan-3, 5-dione: EtOH (199)
$C_{10}H_{18}O_3$	Ethyl diethylacetoacetate (68,† 255†); EtOH (204,† 220, 226, 609); $H_2O$ (204†); cf. p. 360	$C_{11}H_{14}ClNO_2$	Hydrastinine hydrochloride: $H_2O$ (145)
$C_{10}H_{18}NO$	Menthone oxime: EtOH (533)	$C_{11}H_{14}ClN_2O$	4-Aminoantipyrine hydrochloride: EtOH (478)
$C_{10}H_{20}O$	Menthol: EtOH (533)	$C_{11}H_{14}Cl_2O_2$	Cyclohexanespiro-4, 4-dichlorocyclohexan-3, 5-dione: EtOH (199)
$C_{11}H_8Cl_2O_2$	Cyclopentadienechloranil (411)	$C_{11}H_{14}N_2O$	Cytisine: v. p. 360
$C_{11}H_7BrN_2O_4$	<i>p</i> -Bromophenylacetyloximidoxazolone: Et <sub>2</sub> O (243)	$C_{11}H_{14}O$	Formylcamphor anhydride (416)
$C_{11}H_7N$	$\alpha$ ( $\beta$ )-Naphthonitrile: v. p. 360	$C_{11}H_{14}O$	<i>ar</i> -Tetrahydro- $\alpha$ ( $\beta$ )-naphthyl methyl ether: EtOH (360)
$C_{11}H_8O_2$	$\alpha$ ( $\beta$ )-Naphthoic acid: v. p. 360	$C_{11}H_{14}O_2$	Methylisoeugenol (150†)
$C_{11}H_8O_2$	$\beta$ -2-Naphthol-3-carbonic acid, Na salt: EtOH (385)	$C_{11}H_{14}O_2$	Ethyl $\alpha$ -hydrocoumarate and Na salt: EtOH (+NaOEt) (385)
$C_{11}H_8BrIN$	Iodophenylpyridinium bromide: EtOH (338)	$C_{11}H_{14}O_7$	Diethyl xanthochelidonate: $H_2O$ , EtOH, $CHCl_3$ (21)
$C_{11}H_8I_2N$	Iodophenylpyridinium iodide: EtOH (338)	$C_{11}H_{16}BrO_2$	Cyclohexanespiro-4-bromocyclohexan-3, 5-dione: EtOH (199)
$C_{11}H_8N$	Phenylpyridine, salts and derivatives (338)	$C_{11}H_{16}BrO_2$	Bromoformylcamphor (416)
$C_{11}H_8N$	4-Phenylpyridine: Vap. (520)	$C_{11}H_{16}N$	4-Phenylpiperidine: EtOH (+acid), Vap. (520)
$C_{11}H_8NO_2$	Diketo- <i>o</i> ( <i>m</i> , <i>p</i> )-tolylpyrroline: EtOH (512†)	$C_{11}H_{16}NO$	<i>p</i> -Toluidineacetaldehyde condensation compounds (507)
$C_{11}H_8NO_2$	Quininic acid: v. p. 360	$C_{11}H_{16}N_2O_2$	4-Hydroxy-2-methyl-5-isopropylbenzeneazoformamide: EtOH + NaOH (293)
$C_{11}H_{10}$	$\alpha$ -Methylnaphthalene (432†); cf. p. 360	$C_{11}H_{16}BrNO_2$	Bromocamphorcarboxylic amide (414)
$C_{11}H_{10}$	$\beta$ -Methylnaphthalene (432†); hexane, Vap. (372†); cf. p. 360	$C_{11}H_{16}Br_2O$	$\alpha$ , $\omega$ -Dibromomethylcamphor: EtOH (412)
$C_{11}H_{10}IN$	Phenylpyridinium iodide: $CHCl_3$ (338)	$C_{11}H_{16}N_2$	Diethyl ketone phenylhydrazones: EtOH + AcOH (40)
$C_{11}H_{10}N_2O_2$	Anisalhydantoin, derivatives: EtOH (93)	$C_{11}H_{16}O$	Methylenecamphor (416)
$C_{11}H_{10}O$	$\alpha$ ( $\beta$ )-Naphthyl methyl ether: EtOH (360)	$C_{11}H_{16}O_2$	Formylcamphor: EtOH, NaOEt (416)
$C_{11}H_{10}O_2$	2, 3-Dimethylchromone: EtOH (+alk.) (292†)	$C_{11}H_{16}O_2$	Hydroxymethylenecamphor (560); EtOH (+alk.) (23,† 416)
$C_{11}H_{10}O_2$	Ethyl phenylpropionate (423)	$C_{11}H_{16}O_2$	Cyclohexanespirocyclohexan-3, 5-dione: EtOH (+NaOEt) (199)
$C_{11}H_{10}O_2$	Methyloxindone (230); Na, Rb salts: EtOH (230)	$C_{11}H_{16}O_3$	Camphorcarboxylic acid and Na salt (414)
$C_{11}H_{10}O_2$	Cinnamylideneacetic acid (423)	$C_{11}H_{17}BrO$	$\alpha$ ( $\beta$ , $\omega$ )-Bromomethylcamphor: EtOH (412)
$C_{11}H_{10}O_4$	Ethyl coumaranonecarboxylate and Na salt: EtOH (456)	$C_{11}H_{17}NO$	Aminomethylenecamphor: EtOH (+HCl) (416)
$C_{11}H_{11}ClN_2$	1, <i>o</i> -Tolyl-3(5)-methyl-5(3)-chloropyrazole (554)		
$C_{11}H_{11}NO$	8-Ethoxyquinoline: EtOH (+HCl) (188)		
$C_{11}H_{11}NO_2$	$\beta$ -Indolepropionic acid (648)		
$C_{11}H_{11}NO_2$	$\omega$ -Aminoethylpiperonylcarboxylic anhydride: EtOH (140, 287)		
$C_{11}H_{11}NO_2$	Ketohydrastinine: EtOH (140, 287)		
$C_{11}H_{11}NO_4$	Ethyl <i>o</i> ( <i>m</i> , <i>p</i> )-nitrocinnamate: EtOH (43)		
$C_{11}H_{12}N_2O$	1-Phenyl-2, 3-dimethyl-5-pyrazolone (554)		
$C_{11}H_{12}N_2O$	1, <i>o</i> -Tolyl-3(5)-methyl-5(3)-pyrazolone (554)		



Formula	Name, solvents and literature	Formula	Name, solvents and literature
Ultra-violet and Visible.—(Continued)			
$C_{11}H_{17}NO_2$	Isonitrosocamphor- <i>O</i> -methyl ether: EtOH (31)	$C_{12}H_{10}N_4O_2$	<i>p</i> -Nitroazoaminobenzene, Na salt: EtOH (244)
$C_{11}H_{17}NO_2$	Camphorcarboxylic amide (414)	$C_{12}H_{10}N_4O_4$	3, 3'(5)-Dinitrobenzidine: EtOH, HCl, NaOH (90)
$C_{11}H_{17}N_3O_2$	$\alpha(\beta)$ -Camphorquinonesemicarbazone (368)	$C_{12}H_{10}O$	Diphenyl ether: EtOH (161†); $CHCl_3$ (537); Vap. (161,† 521)
$C_{11}H_{17}N_3O_3$	Ethyl 2, 3, 5-trimethyl-1-ureido-4-pyrrole-carboxylate (362)	$C_{12}H_{10}O$	<i>o</i> -Hydroxydiphenyl: EtOH (+NaOEt) (385)
$C_{11}H_{18}O$	Methylcamphor: EtOH (412)	$C_{12}H_{10}OS$	Diphenyl sulfoxide: EtOH (189)
$C_{11}H_{19}NO_3S$	$\alpha$ -Methylcamphorsulfonamide: EtOH (413)	$C_{12}H_{10}O_2$	Cinnamylideneacrylic acid: EtOH (+NaOEt) (35)
$C_{11}H_{19}N_3O$	Fenchone semicarbazone (245)	$C_{12}H_{10}O_2$	Diphenol: EtOH (409)
$C_{11}H_{20}O_4$	Diethyl diethylmalonate: EtOH (82, 198); (+NaOEt) (82)	$C_{12}H_{10}O_2S$	Diphenyl sulfone: EtOH (189)
$C_{11}H_{22}O$	Methyl nonyl ketone (176, 294, 545†); EtOH (609)	$C_{12}H_{10}O_2S_2$	Diphenyl disulfoxide: EtOH (189)
$C_{12}H_6Br_4N_2O_2$	$\alpha(\beta)$ -Tetrabromo- <i>p</i> -azophenol: EtOH (549)	$C_{12}H_{10}O_3$	Acetyloxindone, Ca, Cs, Li salts: EtOH (230)
$C_{12}H_6N_8O_{12}$	Hexanitrohydrazobenzene: MeOH, $CHCl_3$ , HCl, NaOEt (248)	$C_{12}H_{10}O_4$	Cinnamylidenemalonic acid: EtOH (35, 614); $H_2O$ , HCl, NaOEt (35)
$C_{12}H_6O_2$	Diphenquinone: EtOH (409)	$C_{12}H_{10}O_4$	Ethyl oxindonecarboxylate, Ag,† Ba,† Ca, Cs, K, Li, Na,† Rb,† Sr,† Tl† salts: EtOH (230)
$C_{12}H_6O_2$	Acenaphthenequinone: EtOH (36)	$C_{12}H_{10}O_4S_2$	Diphenyl disulfone: EtOH (189)
$C_{12}H_7NO_3$	Resorufin: EtOH (482†)	$C_{12}H_{10}O_4$	Piperic acid: EtOH (136)
$C_{12}H_8$	Acenaphthylene: EtOH (42)	$C_{12}H_{10}O_4$	Quinhydrone: EtOH (288, 405); Vap. (288)
$C_{12}H_8Br_2N_2O$	Benzeneazo-2, 6-dibromophenol (250)	$C_{12}H_{10}O_4$	Diphenyl sulfide (189); EtOH, Vap. (161)
$C_{12}H_8N_2$	Phenazine: EtOH (234)	$C_{12}H_{10}S$	Diphenyl disulfide: EtOH (161, 189)
$C_{12}H_8N_2O_2$	Benzoquinoneazine (44)	$C_{12}H_{10}S_2$	Diphenylamine: EtOH (13, 410, 537), Vap. (521); cf. p. 360
$C_{12}H_8N_4O_6$	Phenylpicramide: EtOH (218, 248); (+NaOEt) (248)	$C_{12}H_{11}N$	6, 7-Dimethoxyisoquinoline-1-carboxylic acid (137)
$C_{12}H_8O$	Diphenylene oxide: EtOH (138)	$C_{12}H_{11}NO_4$	<i>p</i> -Aminoazobenzene: EtOH (29, 183, 486,† 521, 634); acid (29, 319); Vap. (521)
$C_{12}H_8OS_2$	Thianthrene sulfoxide: EtOH (189)	$C_{12}H_{11}N_3$	Diazoaminobenzene: EtOH (247, 521); Vap. (521)
$C_{12}H_8S_2$	Thianthrene: EtOH (189)	$C_{12}H_{11}N_3$	<i>p</i> -Aminobenzeneazophenol: EtOH, HCl (318)
$C_{12}H_9Br$	4-Bromoacenaphthene: EtOH (518)	$C_{12}H_{11}N_3O$	Diphenylamine- <i>p</i> -diazonium sulfate: $H_2O$ , acid (247)
$C_{12}H_9Cl$	4-Chloroacenaphthene: EtOH (518)	$C_{12}H_{11}N_3O_4S$	Dimethylnaphthalene: hexane, Vap. (372†); cf. p. 360
$C_{12}H_9ClN_4$	Benzeneazobenzenediazonium chloride: EtOH (319)	$C_{12}H_{12}$	Diethyl <i>p</i> -dichlorodihydroxyterephthalate: MeOH, $C_6H_{11}OH$ , $CHCl_3$ (224, 236); EtOH, $Et_2O$ (236)
$C_{12}H_9Cl_2NS$	2, 5-Dichlorobenzenesulfuranilide: $CHCl_3$ (174.2†)	$C_{12}H_{12}Cl_2O_6$	Ben-zidine: EtOH (90, 521); Vap. (521)
$C_{12}H_9I$	4-Iodoacenaphthene: EtOH (518)	$C_{12}H_{12}N_2$	Hydrazobenzene: $CHCl_3$ (537)
$C_{12}H_9IN_2$	Iodoazobenzene: EtOH, HCl (319)	$C_{12}H_{12}N_2$	Luminal: v. p. 360
$C_{12}H_9N$	Carbazole: v. p. 360	$C_{12}H_{12}N_2O_3$	Cinnamylideneacetone: EtOH (+NaOEt) (35)
$C_{12}H_9N_3O_3$	<i>o</i> ( <i>m</i> , <i>p</i> )-Nitrobenzeneazophenol: EtOH (+NaOEt) (44)	$C_{12}H_{12}O$	6(7, 8)-Methoxy-2, 3-dimethylchromone: EtOH (+alk.) (292†)
$C_{12}H_9N_3O_3$	<i>p</i> -Nitrobenzeneazophenol: EtOH (44, 496, 592); K salt: EtOH (592); Na salt (496); EtOH (592)	$C_{12}H_{12}O_3$	1, <i>o</i> -Tolyl-3, 4-dimethyl-5-chloropyrazole (554)
$C_{12}H_9N_3O_4$	<i>p</i> -Dinitrodiphenylamine, Na salt: EtOH (244)	$C_{12}H_{13}ClN_2$	$\alpha(\beta)$ -Dimethylnaphthylamine: v. p. 360
$C_{12}H_9N_3O_4$	Phenyl-2, 4-dinitroaniline: EtOH (218)	$C_{12}H_{13}N$	Diethyl dihydroxyterephthalate dibromide: EtOH (235)
$C_{12}H_9N_3O_4$	<i>m</i> , <i>p</i> -Dinitrodiazoaminobenzene and derivatives: EtOH (593)	$C_{12}H_{14}Br_2O_6$	Diethyl $\beta$ -dichlorosuccinylsuccinate: EtOH (235)
$C_{12}H_9N_3O_4$	<i>p</i> , <i>p'</i> -Dinitrodiazoaminobenzene, Na salt: EtOH (244)	$C_{12}H_{14}Cl_2O_6$	1, <i>o</i> -Tolyl-3, 4-dimethyl-5-pyrazolone (554)
$C_{12}H_{10}$	Diphenyl (37,† 42); EtOH (431†); Vap. (521); cf. p. 360	$C_{12}H_{14}N_2O$	Apiole: EtOH (119)
$C_{12}H_{10}$	Acenaphthene (42); EtOH, Vap. (518)	$C_{12}H_{14}O_4$	Isoapiole: EtOH (119)
$C_{12}H_{10}N_2$	Azobenzene (196,† 229); EtOH (29, 40, 83.3, 117, 213,† 216, 247, 422,† 486,† 521, 537); acid (29, 83.3, 216, 633); $CHCl_3$ (216, 537); MeOH (216); ligroin (83.3); Vap. (521); cf. p. 360	$C_{12}H_{14}O_4$	Diethyl phthalate: $Et_2O$ (577)
$C_{12}H_{10}N_2O$	Azoxybenzene: EtOH (521, 526,† 434†); Vap. (521)	$C_{12}H_{14}O_6$	Diethyl dihydroxyterephthalate: EtOH (235); MeOH, $CHCl_3$ (236)
$C_{12}H_{10}N_2O$	Benzenediazophenol (196†); EtOH (183, 250, 550, 592, 633); $H_2SO_4$ (216); HCl, NaOEt (633); K salt (592); Li salt: $Et_2O$ (250); Rb salt: EtOH, $C_6H_5N$ (250)	$C_{12}H_{14}INO(?)$	Anisylpyridinium iodide: $CHCl_3$ (338)
$C_{12}H_{10}N_2O_2$	Azophenol: EtOH (219, 549, 634); $Et_2O$ (219); (+NaOEt) (634)	$C_{12}H_{15}NO$	Benzoylpiperidine: EtOH, Vap. (520)
		$C_{12}H_{15}NO_3$	Hydrocotarnine (144†); HCl (223); hexane (603,† 605†); var. solvents (606†)
		$C_{12}H_{15}NO_4$	Cotarnine: EtOH (144,† 264, 606†); $H_2O$ , $Et_2O$ , hexane (144,† 606†); $CHCl_3$ , NaOH (144†)



Formula	Name, solvents and literature	Formula	Name, solvents and literature
<b>Ultra-violet and Visible.—(Continued)</b>			
$C_{12}H_{16}Br_4O_6$	Diethyl tetrabromosuccinylsuccinate: EtOH (235)	$C_{13}H_{11}N_3O_2$	<i>p</i> -Nitrobenzaldehyde phenylhydrazone: EtOH (314)
$C_{12}H_{16}ClNO_2$	6, 7-Dimethoxy-3, 4-dihydroisoquinoline methochloride: $H_2O$ (631)	$C_{13}H_{11}N_3O_2$	Benzaldehyde <i>p</i> -nitrophenylhydrazone: EtOH (+NaOH) (314)
$C_{12}H_{16}ClNO_4$	Cotarnine hydrochloride: EtOH (144,† 223); $H_2O$ (223, 606†); $CHCl_3$ , HCl (223)	$C_{13}H_{11}N_3O_4$	<i>o</i> -Tolyl-2, 4-dinitroaniline (217); EtOH, $CHCl_3$ (218)
$C_{12}H_{16}INO_4$	Cotarnine hydroiodide: EtOH (223)	$C_{13}H_{11}N_3O_4$	<i>m</i> -Tolyl-2, 4-dinitroaniline: EtOH, $CHCl_3$ (218)
$C_{12}H_{16}O$	Methyl duryl ketone (176)	$C_{13}H_{11}N_3O_4$	<i>p</i> -Tolyl-2, 4-dinitroaniline: EtOH (218)
$C_{12}H_{16}O_6$	Diethyl succinylsuccinate: $Et_2O$ , AcOH + $H_2SO_4$ , MeOH, EtOH (235)	$C_{13}H_{11}N_3O_4$	2, 4-Dinitrobenzylaniline: EtOH (477)
$C_{12}H_{17}NO_2$	6, 7-Dimethoxy-2-methyltetrahydroisoquinoline: $CHCl_3$ , $Et_2O$ (631)	$C_{13}H_{11}NS$	Thiobenzanilide (445)
$C_{12}H_{17}NO_4$	Diethyl 2, 5-dimethyl-3, 4-pyrroledicarboxylate (362)	$C_{13}H_{12}$	Diphenylmethane (37†); EtOH (13, 443,† 483.3, 537); Vap. (521); cf. p. 360
$C_{12}H_{18}$	Hexamethylbenzene: EtOH (386, 403, 524†)	$C_{13}H_{12}IN$	Benzylideneaniline hydroiodide (337); EtOH (43)
$C_{12}H_{18}N_2$	Diethyl ketone phenylmethylhydrazone: EtOH (40)	$C_{13}H_{12}N_2$	Benzaldehyde phenylhydrazone: EtOH (40, 620); (+AcOH) (620)
$C_{12}H_{18}N_2O_6$	$\alpha$ -Glucose phenylhydrazone (45)	$C_{13}H_{12}N_2O$	Benzeneazoisole (196†)
$C_{12}H_{18}O_2$	Acetylcamphor: EtOH (+NaOEt) (416)	$C_{13}H_{12}N_2O$	Benzeneazo- <i>m</i> ( <i>p</i> )-cresol: EtOH, HCl, NaOEt (633)
$C_{12}H_{18}O_3$	Camphorylacetic acid (559)	$C_{13}H_{12}N_2O$	<i>s</i> -Benzoylphenylhydrazine: EtOH (457)
$C_{12}H_{18}O_3$	Methyl camphocarboxylate: NaOEt (414)	$C_{13}H_{12}N_2O$	Benzeneazophenyl methyl ether (196†)
$C_{12}H_{18}O_6$	Diethyl diacetylsuccinate: EtOH (+alk.) (23†)	$C_{13}H_{12}N_2O$	1, 1'(2)-Diphenylurea: EtOH (522)
$C_{12}H_{20}OS_2$	Methyl bornylxanthate: EtOH (97)	$C_{13}H_{12}N_2O_2$	<i>p</i> -Methoxybenzeneazophenol: EtOH (634)
$C_{12}H_{20}OS_2$	Methyl fenchylxanthate (97)	$C_{13}H_{12}N_2S$	<i>s</i> -Diphenylthiocarbamide: EtOH (522)
$C_{12}H_{20}O_2$	Tetraethyldiketocyclobutane: hexane (370,† 371†)	$C_{13}H_{12}N_2S$	Benzeneazothioanisole (160)
$C_{12}H_{20}O_6$	Diethyl diethyloxalacetate: EtOH (237)	$C_{13}H_{12}O$	Phenyl benzyl ether: $CHCl_3$ (537); Vap. (521, 537)
$C_{12}H_{22}$	Dimethyldecadiene (560)	$C_{13}H_{12}O$	Diphenylcarbinol: EtOH (483.3)
$C_{12}H_{22}O_{11}$	Cane sugar (265,† 532, 594)	$C_{13}H_{12}O_3$	Ethyl $\beta$ -2-naphthol-3-carboxylate: EtOH (385)
$C_{12}H_{22}O_{11}$	Lactose: $H_2O$ (532)	$C_{13}H_{12}O_6$	Ethyl coumaranonecarboxylate acetate: EtOH (456)
$C_{12}H_{24}O_2$	Lauric acid: EtOH (252)		
$C_{12}H_{26}O$	<i>d</i> ( <i>l</i> )-Laurinol: EtOH (225)	$C_{13}H_{13}N$	Benzylaniline (537)
$C_{12}H_{26}IN$	Tetrapropylammonium iodide: $CHCl_3$ , EtOH (242)	$C_{13}H_{13}N_3$	<i>o</i> -Toluidineazobenzene: EtOH, HCl (233)
$C_{12}H_{18}N_2O_4$	Dinitrofluorene: EtOH (43)	$C_{13}H_{13}N_3O_3S$	<i>o</i> -Toluidineazobenzenesulfonic acid: EtOH (233†)
$C_{12}H_{18}O$	Fluoreneketone: EtOH (615)		
$C_{12}H_{18}ClN_2$	2-Fluorenediazonium chloride: $H_2O$ , acid (247)	$C_{13}H_{13}N_3O_{10}$	Ethyl trinitrophenylmalonate: $CHCl_3$ (249); $H_2O$ (244)
$C_{12}H_{18}NO$	Fluorenone oxime: EtOH (+NaOEt) (400)	$C_{13}H_{14}N_3O_3$	Cyanohydrocotarnine (144)
$C_{12}H_{18}NO_2$	Nitrofluorene: EtOH (43)	$C_{13}H_{14}N_3O_8$	Ethyl dinitrophenylmalonate (249); K salt: EtOH (244, 249)
$C_{12}H_{18}$	Fluorene (42); EtOH, ligroin (71); cf. p. 360		
$C_{12}H_{18}N_2$	Diphenyldiazomethane: v. p. 360	$C_{13}H_{16}O_3$	Ethyl $\beta$ -ethoxycinnamate: EtOH (385)
$C_{12}H_{18}N_2O_2$	Benzylidene- <i>m</i> ( <i>p</i> )-nitroaniline: EtOH (43)	$C_{13}H_{17}NO_3$	Ethyl 3-hydroxy-1, 1-dimethylcyclohexenylidene-5-cyanoacetate: EtOH, NaOEt (112)
$C_{12}H_{18}N_2O_2$	<i>o</i> ( <i>m</i> , <i>p</i> )-Nitrobenzylideneaniline: EtOH (43)		
$C_{12}H_{18}N_4O_6$	$\alpha$ ( $\beta$ )-Methylphenylpicramide: EtOH (217)	$C_{13}H_{17}N_3O_4$	3, 5-Dinitro-4(6)-piperidino- <i>o</i> -xylene: EtOH (477)
$C_{12}H_{18}N_4O_6$	<i>o</i> , <i>p</i> -Tolylpicramide: EtOH, NaOEt (248)		
$C_{12}H_{18}O$	Benzophenone (37, 410, 571,† 572†); EtOH (5.5, 71, 201, 253, 406, 537, 540, 615); $CHCl_3$ + ZnCl <sub>2</sub> (406); Vap. (540); cf. p. 360	$C_{13}H_{18}O_2$	Camphorylideneacetone (559)
$C_{12}H_{18}OS_2$	Diphenyl dithiocarbonate: EtOH (536)	$C_{13}H_{18}O_3$	Acetoxymethylenecamphor (416)
$C_{12}H_{18}O_3$	Phenyl benzoate: EtOH (384)	$C_{13}H_{18}NO_4$	Diethyl 1, 2, 5-trimethyl-3, 4-pyrroledicarboxylate (362)
$C_{12}H_{18}O_3S$	Phenyl thiocarbonate (536)		
$C_{12}H_{18}O_3$	Phenyl carbonate: EtOH (536)	$C_{13}H_{20}N_2O_6$	Glucose phenylmethylhydrazone (45)
$C_{12}H_{18}O_3$	Phenyl salicylate: EtOH (384, 386)	$C_{13}H_{20}O$	Ionone (176, 410)
$C_{12}H_{18}S_3$	Phenyl trithiocarbonate: EtOH (536)	$C_{13}H_{20}O_2$	Ethoxymethylenecamphor (416)
$C_{12}H_{11}ClN_2O_3S$	4-Chloro-2-nitrophenylsulfurmethylanilide: $CHCl_3$ (174.2†)	$C_{13}H_{20}O_2$	Propionylcamphor: EtOH (+NaOEt) (416)
$C_{12}H_{11}ClN_2O_4$	Phenazonium methylperchlorate: EtOH (234)	$C_{13}H_{20}O_2$	Methyl methylcamphorcarboxylate (414)
$C_{12}H_{11}IN_2$	Phenazonium methiodide: EtOH (234)	$C_{13}H_{20}O_2$	Ethyl camphorcarboxylate: NaOEt (414)
$C_{12}H_{11}N$	Benzylideneaniline (337); EtOH (43)	$C_{13}H_{22}$	Dimethylundecatriene (560)
$C_{12}H_{11}NO$	Benzanilide: EtOH (119)	$C_{13}H_{22}O_3$	Menthyl pyruvate: $C_6H_6$ (559)
$C_{12}H_{11}NO$	Benzophenoneoxime: EtOH (119, 400); (+NaOEt) (400)	$C_{14}H_8O_2$	Anthraquinone (36, 432,† 464); EtOH (409); Vap. (531)
$C_{12}H_{11}N_3O_2$	<i>o</i> ( <i>m</i> )-Nitrobenzaldehyde phenylhydrazone: EtOH (40)	$C_{14}H_8O_3$	Phenanthraquinone (36, 406, 432†)
		$C_{14}H_8O_3$	9-Ketofluorene-4-carboxylic acid: EtOH (616)
		$C_{14}H_8NO_2$	Phthalanil: EtOH, $H_2SO_4$ (500)
		$C_{14}H_8NO_3$	Nitroanthrone: EtOH, $CHCl_3$ (246)



Formula	Name, solvents and literature	Formula	Name, solvents and literature
Ultra-violet and Visible.—(Continued)			
$C_{14}H_{10}$	Anthracene (42, 191†, †); EtOH (213, † 261, 335, † 426, † 431, † 483.3); $(CH_3)_2CO$ , $CHCl_3$ , ligroin, xylene, isoBuOH, $Et_2O$ , amylalc. (426)	$C_{14}H_{14}N_2$	Acetophenone phenylhydrazone: EtOH + AcOH (40)
$C_{14}H_{10}$	Phenanthrene (42, 195†); EtOH (261, 431†); hexane (606†)	$C_{14}H_{14}N_2$	Benzaldehyde phenylmethylhydrazone: EtOH (40)
$C_{14}H_{10}$	Tolane (423); EtOH (619)	$C_{14}H_{14}N_2O$	Anisaldehyde phenylhydrazone: EtOH + AcOH (620)
$C_{14}H_{10}O$	Diphenylketene: hexane (370, † 371†)	$C_{14}H_{14}N_2O$	Benzeneazo- <i>m(p)</i> -cresetole: EtOH, HCl (633)
$C_{14}H_{10}O_2$	Indonocyclomethylacetoethylene (513)	$C_{14}H_{14}N_2O$	Benzeneazophenetole (196, † 250†); EtOH (293, 633); HCl (633)
$C_{14}H_{10}O_2$	Benzil (36); EtOH (253); cf. p. 360	$C_{14}H_{14}N_2O$	Benzoylcarbinol phenylhydrazone (45)
$C_{14}H_{10}O_2S_2$	Diphenyl dithiooxalate: EtOH (536†)	$C_{14}H_{14}N_2O$	<i>p</i> -Hydroxybenzaldehyde phenylmethylhydrazone: EtOH, NaOEt (634)
$C_{14}H_{10}O_3$	<i>o</i> -Benzoylbenzoic acid: EtOH (253); Na salt: NaOH (253)	$C_{14}H_{14}N_2O$	Salicylaldehyde phenylmethylhydrazone: EtOH, NaOEt (634)
$C_{14}H_{10}O_3$	Oxyphenylphthalide, and neutral alkali salts (462, 463)	$C_{14}H_{14}N_2O$	<i>p</i> -Tolueneazo- <i>p</i> -cresol: EtOH, HCl, NaOEt (633)
$C_{14}H_{10}O_4$	Diphenyl oxalate: EtOH (536)	$C_{14}H_{14}N_2O_3$	Azoxyanisole (526, 548)
$C_{14}H_{11}NO_2$	<i>anti(syn)</i> -Benziloxime: EtOH (217); Na salts: EtOH + NaOH (217)	$C_{14}H_{14}N_4$	Glyoxal phenylosazone (45)
$C_{14}H_{11}NO_2$	<i>p</i> -Nitrostilbene: EtOH (315)	$C_{14}H_{14}N_4O_2$	<i>m(p)</i> -Nitrobenzeneazodimethylaniline (44)
$C_{14}H_{11}NO_2$	<i>p</i> -Nitro- <i>p'</i> -hydroxystilbene: EtOH (+NaOH) (315)	$C_{14}H_{14}N_4O_4$	<i>m(o)</i> -Dinitrotolidine (477)
$C_{14}H_{11}O_6$	2, 4-Dihydroxy- <i>o</i> -benzoylbenzoic acid (484.2)	$C_{14}H_{14}OS$	Dibenzyl sulfoxide: EtOH (189)
$C_{14}H_{12}$	Dihydroanthracene (42)	$C_{14}H_{14}O_2S$	Dibenzyl sulfone: EtOH (189)
$C_{14}H_{12}$	Diphenylethylene: hexane (370, † 371†); cf. p. 360	$C_{14}H_{14}O_4$	Dimethyl cinnamylidenemalonate: $H_2O$ , EtOH (35)
$C_{14}H_{12}$	Stilbene: EtOH (42, 117, 247, 315, 384, 385, 393, 423, 619); $CHCl_3$ (393); cf. p. 360	$C_{14}H_{14}S$	Dibenzyl sulfide: EtOH (189, 536†)
$C_{14}H_{12}IN$	Phenanthridine methiodide (629)	$C_{14}H_{14}N$	Dibenzylamine: EtOH (537)
$C_{14}H_{12}IN$	Acridine methiodide: EtOH, NaOH (629)	$C_{14}H_{14}NO_2$	Diketo- <i>p</i> -cumylpyrroline: EtOH (512†)
$C_{14}H_{12}N_2O$	Phenylglyoxal phenylhydrazone (45)	$C_{14}H_{14}N_2$	<i>p</i> -Dimethylaminoazobenzene: EtOH (29, 216, 228, 229, 634); acid (29, 216, 229, 233); alk. (229, 233)
$C_{14}H_{12}N_2O_2$	<i>p</i> -Acetylbenzeneazophenol: EtOH (+NaOH) (316)	$C_{14}H_{14}N_2O$	<i>p</i> -Dimethylaminobenzeneazophenol: EtOH, HCl (318)
$C_{14}H_{12}N_2O_2$	Benzeneazophenyl acetate (196†)	$C_{14}H_{14}N_2O_2S$	Dimethylaminoazobenzenesulfonic acid: $H_2SO_4$ (229); Na salt: $H_2O$ (229)
$C_{14}H_{12}N_2O_2$	Piperonal phenylhydrazone: EtOH (+AcOH) (620)	$C_{14}H_{14}$	Tetramethylnaphthalene (324)
$C_{14}H_{12}N_2O_4$	<i>dl-m</i> -Azophenolmandelic acid: EtOH, NaOH (83.5)	$C_{14}H_{14}ClN_2$	Dimethylaminoazobenzene hydrochloride: EtOH + HCl (216)
$C_{14}H_{12}N_4O_6$	Methyl- <i>o(p)</i> -tolylpicramide: EtOH (218)	$C_{14}H_{14}Cl_2O_6$	Diethyl <i>p</i> -dichlorodimethoxyterephthalate: (236)
$C_{14}H_{13}O$	Phenyl benzyl ketone: EtOH, Vap. (537)	$C_{14}H_{14}N_2O_2$	Phenylazodimethyldihydroresorcinol: EtOH (+ $C_6H_5N$ ), (+NaOEt) (401)
$C_{14}H_{13}O$	Desoxybenzoin: $CHCl_3$ (392)	$C_{14}H_{14}N_4$	<i>p</i> -Aminobenzeneazodimethylaniline: EtOH + HCl (229)
$C_{14}H_{13}O$	<i>p</i> -Hydroxystilbene: EtOH (+NaOH) (315, 385)	$C_{14}H_{14}N_4$	Dimethylaminobenzeneazoaniline: EtOH + HCl (229)
$C_{14}H_{13}O_2$	Benzoin: v. p. 360	$C_{14}H_{14}O$	5-Acetyl-3-phenyl-4-methyl- $\Delta^2$ -cyclopentene: $C_6H_6$ (513)
$C_{14}H_{13}O_2$	3-Acetyl-1-phenyl-4-methyl-1, 3-cyclobutadiene-2-carboxylic acid: EtOH (513)	$C_{14}H_{14}O_6$	Diethyl dimethoxyterephthalate (236)
$C_{14}H_{13}O_2$	1, 2-Diketo-5-acetyl-3-phenyl-4-methyl- $\Delta^2$ -cyclopentene, and Na salt: EtOH (513)	$C_{14}H_{14}NO_4$	Diethyl collidinedicarboxylate: EtOH (386)
$C_{14}H_{13}O_2$	4-Keto-3-acetyl-5-benzylidene-2-methylhydrofuran (513)	$C_{14}H_{14}O_2$	Myrtenyl crotonate (560)
$C_{14}H_{13}NO_2$	1, 2-Diketo-5-acetyl-3-phenyl-4-methyl- $\Delta^2$ -cyclopenteneoxime: EtOH (513)	$C_{14}H_{14}O_3$	Ethyl camphorylideneacetate: P (559)
$C_{14}H_{13}NS$	<i>N(S)</i> -Methylthiobenzanilide (445)	$C_{14}H_{14}O_4$	Methyl camphocarboxylate acetate: (414)
$C_{14}H_{13}N_2O$	Acetylaminobenzene: EtOH (634)	$C_{14}H_{14}O_4$	Diethyl dimethylsuccinylsuccinate: EtOH (235)
$C_{14}H_{13}N_2O_2$	Acetophenone <i>p</i> -nitrophenylhydrazone: EtOH + NaOH (314)	$C_{14}H_{14}NO_4$	Diethyl dihydrocollidinedicarboxylate (14); EtOH (386)
$C_{14}H_{13}N_2O_2$	<i>o(m, p)</i> -Nitrobenzaldehyde phenylmethylhydrazone: EtOH (40)	$C_{14}H_{14}O_2$	Butyrylcamphor (416)
$C_{14}H_{13}N_2O_2$	<i>o(m, p)</i> -Nitrobenzeneazophenetole (44†)	$C_{14}H_{14}O_3$	Myrtenyl butyrate (560)
$C_{14}H_{13}N_2O_4$	3, 5-Dinitro-4(6)-anilino- <i>o</i> -xylene: EtOH (477)	$C_{14}H_{14}O_4$	Menthyl acetoacetate: P (559)
$C_{14}H_{13}N_2O_4$	Ethyl- <i>m, p</i> -dinitroazobenzene: EtOH (593)	$C_{14}H_{14}N_2O$	Ketohydrindenophenazine (516†)
$C_{14}H_{13}N_2O_4$	<i>m(p)</i> -Nitrobenzeneazoethylamino- <i>p</i> -nitrobenzene: EtOH (593)	$C_{14}H_{14}O_2$	Benzylidene phthalide: EtOH, $H_2SO_4$ (500)
$C_{14}H_{14}$	Dibenzyl (37, † 42, 423); EtOH (117, 384, 393, 619); cf. p. 360	$C_{14}H_{14}N_2O_2$	Benzeneazocarbonylcoumaranone: EtOH (+NaOEt) (457)
		$C_{14}H_{14}O$	Phenylbenzoylacetylene: EtOH (419)



Formula	Name, solvents and literature	Formula	Name, solvents and literature
<b>Ultra-violet and Visible.—(Continued)</b>			
$C_{15}H_{11}NO_2$	Isonitrosodibenzoylmethane: EtOH, NaOEt (400)	$C_{15}H_{15}IN_2$	Benzeneazophenyltrimethylammonium iodide (229, 319); EtOH (29, 216); $H_2SO_4$ , HCl (29)
$C_{15}H_{11}N_2O$	Quinolineazophenol: EtOH (159)	$C_{15}H_{15}N_2O_2$	Phenylmethylhydrazodimethyldihydroresorcinol: EtOH (401)
$C_{15}H_{11}N_2O$	5-Benzeneazo-8-hydroxyquinoline: EtOH, HCl (159)	$C_{15}H_{15}N_4O_2$	Antipyrine-4-azoethyl methyl ketone: EtOH (+NaOEt) (478)
$C_{15}H_{13}N_2$	Phenanthridine methocyanide: Et <sub>2</sub> O, CHCl <sub>3</sub> (629)	$C_{15}H_{15}O_3$	Santonin: EtOH (448)
$C_{15}H_{13}N_2$	3, 5-Diphenylpyrazole (554)	$C_{15}H_{15}O_4$	Diethylbenzoylsuccinate (24); EtOH (+NaOH) (23)
$C_{15}H_{13}N_2O_2$	Furfuramide: EtOH (273†)	$C_{15}H_{21}NO_3$	Ethyl ethoxy-1, 1-dimethyl- $\Delta^3$ -cyclohexenylidene-5-cyanoacetate: EtOH (112)
$C_{15}H_{13}N_2O_3$	Benzenehydrazocarbonylcoumaranone: EtOH (+NaOH) (457)	$C_{15}H_{24}$	Caryophyllene: EtOH (225)
$C_{15}H_{13}N_4O$	5- <i>p</i> -Aminobenzeneazo-8-hydroxyquinoline: EtOH (159)	$C_{15}H_{24}O_3$	Diethyl camphocarboxylate (414)
$C_{15}H_{13}O$	Benzalacetophenone (534, 619)	$C_{15}H_{25}O_2$	Menthyl isopropylacetate (560)
$C_{15}H_{13}O_2$	$\alpha$ -Phenylcinnamic acid: EtOH (384)	$C_{15}H_{25}O_4$	Diphthalyl: AcOH (500)
$C_{15}H_{13}O_2$	Phenyl cinnamate (384)	$C_{15}H_9NO_2$	Cyanobenzalaphthalid (500)
$C_{15}H_{13}O_2S_2$	Diphenyl dithiomalonate: EtOH (536†)	$C_{15}H_{10}$	Diphenyldiacetylene: EtOH (619)
$C_{15}H_{13}NO_3$	<i>p</i> -Nitro- <i>p'</i> -methoxystilbene: EtOH (315)	$C_{15}H_{11}NO_2$	Diphenylmaleinimide: EtOH (389)
$C_{15}H_{13}N_2O_3$	<i>p</i> -Nitrobenzaldehyde phenylhydrazone, acetyl derivative: EtOH (314)	$C_{15}H_{11}NO_3$	1, 3-Diketo-2-benzylidenehydrindamine: EtOH, AcOH (516)
$C_{15}H_{14}$	$\alpha$ -Methylstilbene: EtOH (384, 393)	$C_{15}H_{11}NO_4$	2, 3-Diketo-4, 5-diphenylpyrroline: EtOH (512)
$C_{15}H_{14}N_2O_2$	<i>p</i> -Acetylbenzeneazo- <i>p</i> -cresol: EtOH (+NaOH) (316)	$C_{15}H_{11}NO_6$	Berberidic acid (287); $H_2O$ (140)
$C_{15}H_{14}N_2O_2$	Benzeneazophenyl propionate (196)	$C_{15}H_{11}N_2O_2$	<i>o</i> ( <i>m</i> , <i>p</i> )-Nitrobenzeneazo- $\alpha$ -naphthol: EtOH, NaOEt (44)
$C_{15}H_{14}O$	Benzylacetophenone: EtOH (619)	$C_{15}H_{11}N_2O_3S$	Diphenylthiovioluric acid: (402); Li salt: MeOH (402); K salt: Me <sub>2</sub> CO (402†)
$C_{15}H_{14}O$	Dibenzyl ketone: EtOH (537)	$C_{15}H_{11}N_3O_4$	Diphenylvioluric acid: CHCl <sub>3</sub> (228, 251); Alk. salt: Me <sub>2</sub> CO, CHCl <sub>3</sub> , AcOH (251); Cs salt: Me <sub>2</sub> CO, CHCl <sub>3</sub> (228); Li salt: Me <sub>2</sub> CO (228)
$C_{15}H_{14}O$	Methoxystilbene: EtOH (315, 385)	$C_{15}H_{12}$	Diphenylbutenine: EtOH (619)
$C_{15}H_{14}N_2O_2$	Nitroacetophenone phenylmethylhydrazone: EtOH (40)	$C_{15}H_{12}N_2$	2, 5(6)-Diphenylpyrazine (635)
$C_{15}H_{14}N_2O_4$	4, 6-Dinitro-3- <i>p</i> -toluidino- <i>o</i> -xylene: EtOH (477)	$C_{15}H_{12}N_2O$	$\beta$ -Naphthoquinone phenylhydrazone: EtOH, NaOEt (634)
$C_{15}H_{14}N_2O_4$	3, 5-Dinitro-4- <i>p</i> -toluidino- <i>o</i> -xylene: EtOH (477)	$C_{15}H_{12}N_3O$	Benzeneazo- $\alpha$ ( $\beta$ )-naphthol: EtOH (+NaOEt) (183, 634)
$C_{15}H_{14}N_2O_4$	3, 5-Dinitro-4-benzylamino- <i>o</i> -xylene: EtOH (477)	$C_{15}H_{12}N_2O_3$	<i>p</i> -Tolueneazoformyloxycoumarone: EtOH (457)
$C_{15}H_{14}N_2O_5$	3, 5-Dinitro-4- <i>c</i> ( <i>p</i> )-anisidino- <i>o</i> -xylene: EtOH (477)	$C_{15}H_{12}O_2$	Diphenyldiketocyclobutane: Et <sub>2</sub> O (370, † 371†)
$C_{15}H_{14}N_2O_5$	3, 5-Dinitro-6- <i>o</i> ( <i>p</i> )-anisidino- <i>o</i> -xylene: EtOH (477)	$C_{15}H_{12}O_3$	Ethyl 9-ketofluorene-4-carboxylate: EtOH (616)
$C_{15}H_{16}$	Phenyl-2, 4-xylylmethane: EtOH (537)	$C_{15}H_{13}BrN_2$	2, 5(6)-Diphenylpyrazine hydrobromide (635)
$C_{15}H_{16}N_2$	Benzylidene- <i>p</i> -dimethylaminoanil (337)	$C_{15}H_{13}ClN_2$	2, 5(6)-Diphenylpyrazine hydrochloride (635)
$C_{15}H_{16}N_2$	<i>p</i> -Dimethylaminobenzylideneanil (337)	$C_{15}H_{13}N$	$\alpha$ ( $\beta$ )-Phenyl-naphthylamine: <i>v. p.</i> 360
$C_{15}H_{16}N_2C$	<i>s</i> -Dibenzylcarbamide: EtOH (522)	$C_{15}H_{14}$	Distyrene, solid and liquid: EtOH (622)
$C_{15}H_{16}N_2O$	Anisaldehyde phenylmethylhydrazone: EtOH (634)	$C_{15}H_{14}$	Diphenylbutadiene: EtOH (619); <i>cf. p.</i> 360
$C_{15}H_{16}N_2O$	$\alpha$ -Methoxybenzaldehyde phenylmethylhydrazone: EtOH (634)	$C_{15}H_{14}O_2S_2$	Diphenyl dithiosuccinate: EtOH (536†)
$C_{15}H_{16}N_2O$	<i>p</i> -Tolueneazo- <i>p</i> -cresetole: EtOH, HCl (633)	$C_{15}H_{14}O_3$	Ethyl $\alpha$ -benzoylbenzoate: EtOH (253)
$C_{15}H_{16}N_2O$	Benzeneazophenyl propyl ether (196†)	$C_{15}H_{15}N$	Cinnamylidene- <i>p</i> -toluidine: EtOH (632)
$C_{15}H_{16}N_4$	Pyruvaldehyde osazone (45)	$C_{15}H_{15}N_2O$	Phenyl styryl ketone semicarbazone (295)
$C_{15}H_{16}O_4$	Picrotoxinine: EtOH (264)	$C_{15}H_{16}$	<i>p</i> -Dimethylstilbene: EtOH (393)
$C_{15}H_{17}BrN_2$	<i>p</i> -Dimethylaminobenzylideneanil hydrobromide (338)	$C_{15}H_{16}$	$\alpha$ , $\beta$ -Dimethylstilbene: EtOH (393)
$C_{15}H_{17}N_2$	Dimethyl- $\alpha$ -toluidineazobenzene: EtOH, HCl (233)	$C_{15}H_{16}N_2O_2$	Benzeneazophenyl butyrate (196†)
$C_{15}H_{17}N_2O$	<i>p</i> -Methoxybenzeneazodimethylaniline: EtOH, HCl (229, 318)	$C_{15}H_{16}$	Diphenylbutane: EtOH (393, 619)
$C_{15}H_{17}N_2O_2S$	Dimethyl- $\alpha$ -toluidineazobenzenesulfonic acid: MeOH, EtOH + HCl (233)	$C_{15}H_{16}N_2$	Cuminal phenylhydrazone: EtOH (+AcOH) (620)
$C_{15}H_{18}$	Azulene (365)	$C_{15}H_{16}N_2O$	Benzeneazophenyl butyl ether (196†)
$C_{15}H_{18}ClN_2$	Benzeneazophenyltrimethylammonium chloride (229); $H_2O$ , HCl (233)	$C_{15}H_{16}N_2O_2$	Azophenetole: EtOH (+NaOEt) (634)
		$C_{15}H_{16}N_2O_3$	Azoxyphenetole: EtOH (526†)
		$C_{15}H_{16}N_4$	Diacetyl phenyllosazone: EtOH (45)
		$C_{15}H_{16}N_4$	Glyoxal phenylmethylosazone (45)
		$C_{15}H_{16}N_4O_3$	Antipyrine-4-azoacetylacetone: EtOH (+NaOEt) (478)



Formula	Name, solvents and literature	Formula	Name, solvents and literature
Ultra-violet and Visible.—(Continued)			
$C_{16}H_{19}BrN_2O$	Camphorquinone <i>p</i> -bromophenylhydrazone: EtOH, NaOEt (45)	$C_{17}H_{20}N_2O_2$	<i>p</i> -Dimethylaminobenzylideneanil acetate (337)
$C_{16}H_{19}Br_2NO_3S$	$\alpha$ -Bromocamphor- $\beta$ -sulfon- <i>p</i> -bromoanilide: EtOH + NaOEt (413)	$C_{17}H_{20}N_4O_4$	Ethyl antipyrine-4-azoacetate: EtOH (+NaOEt) (478)
$C_{16}H_{19}NO_4$	Benzoylecgonine: <i>v. p.</i> 360	$C_{17}H_{20}O$	Benzylidenecamphor (416, 534, 560); EtOH (214, 415†)
$C_{16}H_{19}N_3$	<i>p</i> -Azotoluenedimethylamine: EtOH (247)	$C_{17}H_{20}O_2$	<i>m</i> -Hydroxybenzylidenecamphor: EtOH (214)
$C_{16}H_{20}N_2O$	$\alpha(\beta)$ -Camphorquinone phenylhydrazone: (368); EtOH, NaOEt (45)	$C_{17}H_{21}NO_2$	Apoatropine (194†)
$C_{16}H_{20}O_2$	Tetraallyldiketocyclobutane: (371†); hexane (370†)	$C_{17}H_{21}NO_4$	Hyoscine: EtOH (136)
$C_{16}H_{21}NO_3$	Homoatropine: <i>v. p.</i> 360	$C_{17}H_{21}NO_4$	Cocaine (194†); EtOH (95†, 136)
$C_{16}H_{21}NO_3S$	Camphor- $\beta$ -sulfonanilide: EtOH, +NaOEt (413)	$C_{17}H_{21}N_3O_2$	$\alpha(\beta)$ -Camphorquinone phenylcarbamyldihydrazone (368)
$C_{16}H_{22}$	Dimethylphenyloctadiene (560)	$C_{17}H_{22}ClNO_4$	Cocaine hydrochloride: EtOH (95†); <i>cf. p.</i> 360
$C_{16}H_{22}O$	Benzoyltetramethylcyclopentane: P (559)	$C_{17}H_{22}N_2O$	Camphorquinone phenylmethylhydrazone (45)
$C_{16}H_{24}BrNO_2$	Bromocamphorcarboxylic piperidide (414)	$C_{17}H_{22}N_6O_4$	<i>o</i> -Nitrobenzenediazo-4-semicarbazinocamphor (157)
$C_{16}H_{26}ClO_3$	Amyl chlorocamphorcarboxylate (414)	$C_{17}H_{23}NO_3$	Atropine (194†); EtOH (136)
$C_{16}H_{26}NO_2$	Camphocarboxylic piperidide (414)	$C_{17}H_{23}NO_3$	Hyoscyamine: EtOH (136)
$C_{16}H_{26}O_3$	Amyl camphocarboxylate: NaOEt (414)	$C_{17}H_{26}NO_7S$	Hyoscyamine bisulfate: $H_2O$ (95†)
$C_{16}H_{26}O_4$	Menthyl diacetate: $C_6H_6$ (559)	$C_{17}H_{26}O_2$	Myrtenyl hexahydrobenzoate (560)
$C_{16}H_{28}O_2$	Tetrapropyldiketocyclobutane: hexane (370†, 371†)	$C_{18}H_9ClO_3$	1-Chloro-6-hydroxynaphthacenequinone: EtOH, NaOEt, $H_2SO_4$ , $H_3BO_3$ (41)
$C_{16}H_{34}O$	Cetyl alcohol (438)	$C_{18}H_9NO_4$	Diketohydrindylidenediketohydrindamine: AcOH (516); $NH_4$ salts (516)
$C_{17}H_{11}NO_4$	2, 3-Diketo-4-phenyl-5-piperonylpyrroline: EtOH (512)	$C_{18}H_9N_2O_7$	1-Hydroxy-2, 6-dinitronaphthacenequinone: EtOH, NaOEt, $H_2SO_4$ , $H_3BO_3$ (41)
$C_{17}H_{12}N_2O_4$	Benzeneazocarbonyl-2-acetylcoumaranone: EtOH (457)	$C_{18}H_{10}O_2$	Naphthacenequinone: EtOH, NaOEt, $H_2SO_4$ , $H_3BO_3$ (41)
$C_{17}H_{12}O_3$	8-Phenylindoneacetic acid: EtOH (616)	$C_{18}H_{10}O_3$	<i>allo</i> -Chrysoketone-1-carboxylic acid: EtOH (238, 616); $H_2SO_4$ , AcOH (238)
$C_{17}H_{12}O_4$	Bis(furfurylidenemethyl)-pyrone: EtOH (76)	$C_{18}H_{10}O_3$	1-Hydroxynaphthacenequinone: EtOH, NaOEt, $H_2SO_4$ , $H_3BO_3$ (41)
$C_{17}H_{13}ClO_4$	Bis(furfurylidenemethyl)pyrone hydrochloride: HCl, EtOH (76)	$C_{18}H_{10}O_4$	1, 6(7, 8, 9, 10)-Dihydroxynaphthacenequinone: EtOH, NaOEt, $H_2SO_4$ , $H_3BO_3$ (41)
$C_{17}H_{13}NO_2$	2, 3-Diketo-4-phenyl-5- <i>o</i> ( <i>m</i> , <i>p</i> )-tolylpyrroline: EtOH (512)	$C_{18}H_{10}O_6$	1, 2, 6-Trihydroxynaphthacenequinone: EtOH, NaOEt, $H_2SO_4$ , $H_3BO_3$ (41)
$C_{17}H_{13}NO_3$	1, 3-Diketo-2-anisylidenehydrindamine: AcOH (516)	$C_{18}H_{10}O_7S$	1, 5-Dihydroxynaphthacenequinonesulfonic acid: EtOH, NaOEt, $H_2SO_4$ , $H_3BO_3$ (41)
$C_{17}H_{13}NO_3$	2, 3-Diketo-4-phenyl-5- <i>p</i> -anisylpyrroline: EtOH (512)	$C_{18}H_{11}Cl_3N_2$	Dichlorophenylphenazonium chloride: EtOH (16)
$C_{17}H_{13}N_3$	2(3), <i>p</i> -Tolyl- $\alpha$ , $\beta$ -naphtho-(iso)triazole: EtOH (473)	$C_{18}H_{11}NO_2$	Quinophthalone: EtOH (489.5)
$C_{17}H_{13}N_3O_6S$	Toluene- <i>p</i> -sulfonyl-1, 6-dinitro- $\beta$ -naphthylamine: EtOH (472)	$C_{18}H_{11}NO_3$	1-Amino-6-hydroxynaphthacenequinone: EtOH, NaOEt, $H_2SO_4$ , $H_3BO_3$ (41)
$C_{17}H_{14}N_2O$	$\alpha$ -Naphthoquinone phenylmethylhydrazone: EtOH (634)	$C_{18}H_{11}NO_4$	1-Amino-6, 8(9)-dihydroxynaphthacenequinone: EtOH, NaOEt, $H_2SO_4$ , $H_3BO_3$ (41)
$C_{17}H_{14}N_2O_4S$	Toluene- <i>p</i> -sulfonyl-1-nitro- $\beta$ -naphthylamine: EtOH (472)	$C_{18}H_{11}NO_5S_2$	Quinophthalonedisulfonic acid, Na salt (489.5)
$C_{17}H_{14}O$	Dibenzalacetone (410, 411); EtOH, $H_2SO_4$ (13, 406); AcOH + $H_2SO_4$ , $CHCl_3$ + $SnCl_4$ (406)	$C_{18}H_{12}$	Chrysene (42); EtOH (431†)
$C_{17}H_{14}O$	Cinnamylidenacetophenone: EtOH (614)	$C_{18}H_{12}N_2O_2$	Hydroxyaposafrane: NaOH, HCl (16)
$C_{17}H_{14}O_4$	Ethyl benzil- <i>o</i> -carboxylate: EtOH (253)	$C_{18}H_{12}N_4O$	Quinolineazo-8-hydroxyquinoline: EtOH (159)
$C_{17}H_{16}N_2$	$\alpha$ - <i>p</i> -Toluidino- $\gamma$ -phenylisocrotononitrile: EtOH (632)	$C_{18}H_{13}N_5O_3$	<i>p</i> '-Nitro- <i>p</i> '-hydroxy- <i>p</i> -bisazobenzene: EtOH (496); Na salt: (496)
$C_{17}H_{16}N_2O_3$	Ethyl phenylhydrazinocoumaranonecarboxylate: EtOH (457)	$C_{18}H_{14}ClN_3$	Aminophenylphenazonium chloride: $H_2O$ (289)
$C_{17}H_{17}ClN_2$	$\alpha$ - <i>p</i> -Toluidino- $\gamma$ -phenylisocrotononitrile hydrochloride: EtOH (632)	$C_{18}H_{14}N_2O$	Benzeneazophenyl phenyl ether (196†)
$C_{17}H_{17}NO_2$	Apomorphine (195†); EtOH + HCl (264)	$C_{18}H_{14}N_2O_2$	<i>p</i> -Acetylbenzeneazo- $\alpha(\beta)$ -naphthol: EtOH (+NaOH) (316)
$C_{17}H_{18}ClNO_2$	Apomorphine hydrochloride: EtOH (264, 606†)	$C_{18}H_{14}N_2O_2$	Acetyl- $\beta$ -naphthoquinone phenylhydrazone: (634)
$C_{17}H_{19}NO_2$	Piperine: EtOH (136, 264); <i>Vap.</i> (520)	$C_{18}H_{14}N_2O_2$	Benzeneazo- $\alpha(\beta)$ -naphthyl acetate: EtOH (634)
$C_{17}H_{19}NO_3$	Morphine: (137, 195†); EtOH (140, 264, 287, 606†); HCl, NaOH (75)	$C_{18}H_{14}N_2O_4$	<i>dl-m</i> -Azo- $\beta$ -naphtholmandelic acid: EtOH, NaOH (83.5)
$C_{17}H_{19}N_3O_2$	Ethyl dimethylanilineazobenzoate: EtOH (229)	$C_{18}H_{14}O_3$	Methyl $\gamma$ -phenylindoneacetate: EtOH (616)
$C_{17}H_{20}N_2O$	4, 4'-Tetramethyldiaminobenzophenone: EtOH (30, 201†, 409); HCl (30)	$C_{18}H_{14}O_6$	Monoethyl benzil- <i>o</i> -dicarboxylate (keto and lactone forms): EtOH (253)
		$C_{18}H_{15}As$	Arsenic triphenyl: $CHCl_3$ (537)



Formula	Name, solvents and literature	Formula	Name, solvents and literature
<b>Ultra-violet and Visible.—(Continued)</b>			
$C_{18}H_{15}ClN_4$	Phenosafranine chloride: $H_2O$ , $HCl$ (16)	$C_{19}H_{14}O_6S$	Phenolsulfonephthalein: $EtOH$ , $KOH$ (333†)
$C_{18}H_{15}N$	Triphenylamine (410); $EtOH$ (13)	$C_{19}H_{15}Cl$	Triphenylchloromethane: $EtOH$ (13, 406, 483.3); $CHCl_3 + SnCl_4$ (406); $Et_2O$ (5.5)
$C_{18}H_{15}O_4P$	Triphenyl phosphate: $EtOH$ , Vap. (242)	$C_{19}H_{15}N$	Diphenylmethylenephénylimine (337)
$C_{18}H_{15}P$	Triphenylphosphine: $EtOH$ , Vap. (242)	$C_{19}H_{15}N$	Dihydrophenylacridine (146)
$C_{18}H_{15}N_2$	Diphenyl- <i>p</i> -phenylenediamine (410)	$C_{19}H_{15}N$	Benzophenoneanil: $CHCl_3$ (543)
$C_{18}H_{15}N_2O$	Benzeneazo- $\alpha$ -naphthyl ethyl ether: $EtOH$ (634)	$C_{19}H_{15}NO_2$	<i>p</i> -Nitrotriphenylmethane and Na salt: $EtOH$ (244)
$C_{18}H_{15}N_2O_2$	1, 3-Diketo-2- <i>p</i> -dimethylaminobenzylidene-hydrindamine: $AcOH$ (516)	$C_{19}H_{15}NO_2$	Phenyl diphenylcarbamate: $EtOH$ , Vap. (522)
$C_{18}H_{15}N_2O_2$	<i>p</i> , <i>p'</i> -Dimethoxy-2, 5(6)-diphenylpyrazine: $CHCl_3$ (635)	$C_{19}H_{15}NO_6S$	Phenylacridonium sulfate: $EtOH$ (223)
$C_{18}H_{15}N_2O_4S$	Toluene- <i>p</i> -sulfonylmethyl-1-nitro- $\beta$ -naphthylamine: $EtOH$ (472)	$C_{19}H_{15}N_3$	Benzylideneaminoazobenzene (496)
$C_{18}H_{16}O_2$	Dimethyldiphenyldiketocyclobutane: hexane (370†, 371†)	$C_{19}H_{16}$	Triphenylmethane: $EtOH$ (13, 443†, 483.3); $Et_2O$ (5.5)
$C_{18}H_{16}O_2$	Benzylideneanisylideneacetone: $EtOH$ , $H_2SO_4$ (13)	$C_{19}H_{16}BrN$	Diphenylmethylenephénylimine hydrobromide (337)
$C_{18}H_{16}O_4$	$\alpha$ -Truxillic acid: $EtOH$ (614, 617)	$C_{19}H_{16}ClN$	Benzophenoneanil hydrochloride: $CHCl_3$ (543)
$C_{18}H_{16}O_4$	$\beta$ -Truxillic acid: $EtOH$ (617)	$C_{19}H_{16}IN$	Diphenylmethylenephénylimine hydroiodide (337)
$C_{18}H_{17}BrN_2O_2$	<i>p</i> , <i>p'</i> -Dimethoxy-2, 5(6)-diphenylpyrazine hydrobromide: $CHCl_3$ (635)	$C_{19}H_{16}O$	Triphenylcarbinol (419.2); $H_2SO_4$ (13); $EtOH$ (13, 483.3); $Et_2O$ (5.5)
$C_{18}H_{17}ClN_2O_2$	<i>p</i> , <i>p'</i> -Dimethoxy-2, 5(6)-diphenylpyrazine hydrochloride: $CHCl_3$ (635)	$C_{19}H_{16}O$	<i>p</i> -Hydroxytriphenylmethane (5.6)
$C_{18}H_{17}NO_6$	Corydic acid: $H_2O$ (140, 287)	$C_{19}H_{16}O_2$	<i>p</i> -Hydroxytriphenylcarbinol (5.6)
$C_{18}H_{18}$	Retene: (191†)	$C_{19}H_{16}O_4S$	Triphenylcarbonium sulfate (228, 406, 579)
$C_{18}H_{20}O_3$	Piperonylidene camphor (214)	$C_{19}H_{17}NO_2$	2, 3-Diketo-4-phenyl-5- <i>p</i> -cumylpyrroline: $EtOH$ (512)
$C_{18}H_{21}NO_3$	Codeine (140†, 195†, 264); $EtOH$ (606†)	$C_{19}H_{17}N_3$	Triphenylguanidine: $EtOH$ (522)
$C_{18}H_{22}BrNO_4$	<i>o</i> -Hydroxycodine hydrobromide: $H_2O$ (142†)	$C_{19}H_{18}IP$	Triphenylmethylphosphonium iodide: $EtOH$ , $CHCl_3$ , $H_2O$ (242)
$C_{18}H_{22}ClNO_3$	Codeine hydrochloride: $H_2O$ (606†)	$C_{19}H_{18}O_3$	Dianisylideneacetone: $EtOH$ , $H_2SO_4$ (13, 406); $CHCl_3 + SnCl_4$ (406)
$C_{18}H_{22}N_4O_4$	Glucosazone (45)	$C_{19}H_{19}NO_4$	Bulbocapnine (140); $EtOH$ (287)
$C_{18}H_{23}O$	<i>m</i> ( <i>p</i> )-Tolylidenecamphor: $EtOH$ (214)	$C_{19}H_{21}NO_3$	Thebaine: $EtOH$ (264)
$C_{18}H_{23}O_2$	<i>m</i> -Methoxybenzylidenecamphor: $EtOH$ (214)	$C_{19}H_{22}ClNO_3$	Thebaine hydrochloride: $H_2O$ (606†)
$C_{18}H_{23}O_2$	Anisylidenecamphor: $EtOH$ (214)	$C_{19}H_{22}N_2O$	Cinchonidine (140†); $EtOH$ (264)
$C_{18}H_{23}N_3O$	Dipropylaminobenzeneazophenol: $CHCl_3$ (250)	$C_{19}H_{22}N_2O$	Cinchotoxine: <i>v. p.</i> 360
$C_{18}H_{24}O_2$	Anisylcamphor: $EtOH$ (214)	$C_{19}H_{22}N_2O$	Cinchonine (264); $EtOH$ (140, 143, 287); (+ $HCl$ ) (143); <i>cf. p.</i> 360
$C_{18}H_{25}N_3O_2$	<i>p</i> -Toluenediazo- $\psi$ -semicarbazinocamphor (157)	$C_{19}H_{22}N_2O_2$	Cupreine (140†); $EtOH$ (135)
$C_{18}H_{26}OS_2$	Benzyl menthylxanthogenate: $EtOH$ (97)	$C_{19}H_{22}N_2O_2 \cdot 2H_2O$	Apoquinine: <i>v. p.</i> 360
$C_{18}H_{26}O_4$	Amyl camphorcarboxylate acetate (414)	$C_{19}H_{22}N_2O_4$	Quitenine: <i>v. p.</i> 360
$C_{18}H_{26}O_4$	Ethyl camphorcarboxylate valerate (414)	$C_{19}H_{22}O$	Cinnamylidene camphor (534)
$C_{18}H_{32}O_2$	Stearic acid (423)	$C_{19}H_{22}ClN_2O$	Cinchonine hydrochloride; <i>v. p.</i> 360
$C_{18}H_{32}O_3$	Menthyl $\alpha$ , $\alpha$ -diethylacetoacetate: $C_6H_6$ (559)	$C_{19}H_{24}N_2O_2$	Hydrocupreine: <i>v. p.</i> 360
$C_{18}H_{34}O_2$	Elaidic acid (423)	$C_{19}H_{26}O_3$	Menthyl benzoylacetate: $C_6H_6$ (559)
$C_{18}H_{36}O_2$	Stearic acid (423)	$C_{19}H_{28}O_2$	Menthyl hydrocinnamate (560)
$C_{19}H_{12}O_4$	1-Hydroxy-5(8)-methoxynaphthacenequinone: $EtOH$ , $NaOEt$ , $H_2SO_4$ , $H_3BO_3$ (41)	$C_{20}H_6Br_4Cl_4O_4$	Tetrabromophenoltetrachlorophthalein: $EtOH$ , $KOH$ (333†)
$C_{19}H_{15}BrN_2O_4$	Bromodinitrotriphenylmethane: $EtOH$ (244); Na salt: $EtOH + C_6H_6$ (244)	$C_{20}H_6Cl_4I_4O_4$	Tetraiodophenoltetrachlorophthalein (333†)
$C_{19}H_{15}N$	Fluorenoneanil: $CHCl_3$ (543)	$C_{20}H_8Br_4O_5$	Eosin: $H_2O$ (439); alk. (467); $EtOH$ (482†)
$C_{19}H_{15}N$	Phenylacridine: $CHCl_3$ , $EtOH$ (223)	$C_{20}H_8I_4O_6$	Erythrosin: $H_2O$ (439)
$C_{19}H_{15}N_2O_6$	Trinitrotriphenylmethane: $CHCl_3$ (244); Na salt: $EtOH + C_6H_6$ (244)	$C_{20}H_{10}Br_4O_4$	Tetrabromophenolphthalein: $EtOH$ , $KOH$ (333†); $NaOH$ (462, 467); Neutral alkali salts (462)
$C_{19}H_{15}N_3O_7$	<i>p</i> -Trinitrotriphenylcarbinol: $CHCl_3$ , $MeOH$ (239)	$C_{20}H_{10}Cl_2O_3$	Dichlorofluoran: $EtOH$ (484.2)
$C_{19}H_{14}ClN$	Fluorenoneanil hydrochloride: $CHCl_3$ (534)	$C_{20}H_{10}Cl_4O_4$	Tetrachlorophenolphthalein: $EtOH$ , $KOH$ (184, 333†)
$C_{19}H_{14}N_2O$	Benzoylazobenzene: $EtOH$ (457)	$C_{20}H_{10}I_4O_4$	Tetraiodophenolphthalein: $EtOH$ , $KOH$ (333†)
$C_{19}H_{14}N_2O_2$	Benzeneazophenyl benzoate (196†)	$C_{20}H_{12}O_3$	Fluoran: $EtOH$ , $H_2SO_4$ (484.2)
$C_{19}H_{14}N_2O_2$	<i>p</i> -Benzoquinone benzoylphenylhydrazone (633)	$C_{20}H_{12}O_6$	Fluorescein (462); $H_2O$ (439, † 466); $EtOH$ , $AcOH$ , $H_2SO_4$ , $HCl$ , $KOH$ (484.2); Neutral alk. salts (462); Na salt: $H_2O$ (466)
$C_{19}H_{14}N_2O_2$	<i>p</i> -Benzoylbenzeneazophenol (633); $EtOH$ (+ $NaOH$ ) (316)	$C_{20}H_{14}$	Benzylidenefluorene: $EtOH$ (392)
$C_{19}H_{14}N_4O_2$	<i>p</i> -Nitrobenzylideneaminoazobenzene (496)	$C_{20}H_{11}$	$\beta$ , $\beta$ -Dinaphthyl: $EtOH$ , $C_6H_6$ (323)
$C_{19}H_{14}O$	Fuchsone (5.6, 228, 483.4, 579)		
$C_{19}H_{14}O_2$	Benzaurin: $EtOH$ , $HCl$ (483.4, 484.3)		
$C_{19}H_{14}O_3$	Aurin: $KOH$ , $EtOH$ , $HCl$ (483.4)		



Formula	Name, solvents and literature	Formula	Name, solvents and literature
Ultra-violet and Visible.—(Continued)			
$C_{20}H_{14}N_2O$	$\alpha$ , $\alpha'$ -Azoxynaphthalene, (two forms): EtOH (121)	$C_{20}H_{21}Cl_2N_3$	Fuchsine hydrochloride (228)
$C_{20}H_{14}O$	Benzoylfluorene: EtOH (392)	$C_{20}H_{21}NO_4$	Papaverine: EtOH (140, 264, 287, 606†)
$C_{20}H_{14}O$	Diphenylenephenvinyl alcohol: EtOH (392)	$C_{20}H_{21}NO_4$	Tetrahydroberberine (137†); EtOH (140, 287)
$C_{20}H_{14}O_2$	Phthalophenone: EtOH, $H_2SO_4$ (500)	$C_{20}H_{22}ClNO_4$	Papaverine hydrochloride: $H_2O$ (606†)
$C_{20}H_{14}O_2$	Diphenylphthalide: EtOH, $H_2SO_4$ , KOH (483.2)	$C_{20}H_{22}N_2O_2$	1, 4-Dibenzoyl-2(3)-dimethylpiperazine: EtOH (520)
$C_{20}H_{14}O_2$	Terephthalophenone: EtOH, ligroin (71)	$C_{20}H_{22}N_2O_2$	Hydroquinone: v. p. 360
$C_{20}H_{14}O_2S$	$\beta$ -Naphthol sulfides: EtOH (115)	$C_{20}H_{22}O_2$	Camphorylidenebenzylideneacetone: $C_6H_6$ (559)
$C_{20}H_{14}O_3$	Ethyl <i>allo</i> -chrysoketone-1-carboxylate: EtOH (616)	$C_{20}H_{24}N_2O_2$	Chinotoxine: v. p. 360
$C_{20}H_{14}O_3$	Hydroxydiphenylphthalide: EtOH, $H_2SO_4$ (462, 463); Neutral alk. salts (462, 463)	$C_{20}H_{24}N_2O_2$	Quinine (135, 140, 143, 264, 287); cf. p. 360
$C_{20}H_{14}O_4$	Phenolphthalein (462); EtOH, KOH (333†); $H_2SO_4$ (463, 465); $CHCl_3$ + $SnCl_4$ (463); $H_2O$ , Na salt (466); NaOH (467); Neutral alk. salts (462, 463)	$C_{20}H_{24}N_2O_2$	Quinidine (140, 264)
$C_{20}H_{14}O_4$	Isophenolphthalein (483.2)	$C_{20}H_{24}N_2O_2$	Isoquinine: v. p. 360
$C_{20}H_{14}O_4$	Diphenyl phthalate: EtOH (522)	$C_{20}H_{24}O_4$	Ethyl camphorcarboxylate benzoate (414)
$C_{20}H_{16}$	$\alpha$ -Phenylstilbene: EtOH (384); $CHCl_3$ (392, 393)	$C_{20}H_{25}ClN_2O_2$	Quinine hydrochloride (135); cf. p. 360
$C_{20}H_{16}ClN$	Phenylacridonium methochloride: $CHCl_3$ , HCl (223)	$C_{20}H_{25}NO_4$	Laudanine: EtOH (139, 141)
$C_{20}H_{16}IN$	Phenylacridonium methiodide: $CHCl_3$ (223)	$C_{20}H_{25}NO_4$	Tetrahydropapaverine (137, † 287); EtOH (140)
$C_{20}H_{16}N_2O$	Benzilphenylhydrazone: EtOH (+NaOEt) (45)	$C_{20}H_{26}N_2$	Ethylidenexylidine (507)
$C_{20}H_{16}N_2O_2$	<i>o</i> -Benzoylbenzeneazo- <i>p</i> -cresol: EtOH (633)	$C_{20}H_{26}N_2O_2$	Hydrochinotoxine: v. p. 360
$C_{20}H_{16}N_2O_2$	<i>p</i> -Benzoylbenzeneazocresol: EtOH (+NaOH) (316)	$C_{20}H_{26}N_2O_2$	Nitrocamphor anhydride: EtOH (412)
$C_{20}H_{16}O$	Triphenylvinyl alcohol: $CHCl_3$ (392)	$C_{20}H_{26}N_2O_6$	Glucosemethylosazone (45)
$C_{20}H_{16}O$	Fuchsone of <i>o</i> -cresyldiphenylcarbinol (5.6)	$C_{20}H_{26}N_4O_4$	Phenylacridine methocyanide: $Et_2O$ , $CHCl_3$ (629)
$C_{20}H_{16}O_2$	Triphenylacetic acid: EtOH (522)	$C_{21}H_{16}N_4O$	Triketohydrindene diphenylhydrazone: EtOH (516)
$C_{20}H_{16}O_6$	Quinolophthalein, alkali salts (462); NaOH (467); $H_2O$ (466)	$C_{21}H_{16}O$	Benzylidenedesoxybenzoin (534)
$C_{20}H_{17}NO$	<i>N</i> -Methylphenylacridol: MeOH, $CHCl_3$ , $Et_2O$ (146); Salts (215†)	$C_{21}H_{16}O_2$	$\alpha$ , $\alpha'$ -Distyryl- $\gamma$ -pyrone: EtOH, $H_2SO_4$ (76)
$C_{20}H_{17}N_3O$	<i>p</i> -Methoxybenzylideneaminoazobenzene (496)	$C_{21}H_{17}ClO_2$	$\alpha$ , $\alpha'$ -Distyryl- $\gamma$ -pyrone hydrochloride: EtOH, HCl (76)
$C_{20}H_{18}ClNO_4$	Berberine chloride: EtOH, +KOH (630); $H_2O$ (606†)	$C_{21}H_{18}N_2O$	Benzil phenylmethylhydrazone (45)
$C_{20}H_{18}N_2$	Desoxybenzoin phenylhydrazone (45)	$C_{21}H_{18}N_2O_2$	Benzoylbenzeneazo- <i>p</i> -cresetole (633)
$C_{20}H_{18}N_2O$	$\alpha(\beta)$ -Benzoin phenylhydrazone (45)	$C_{21}H_{18}O$	Dicinnamylideneacetone (410); EtOH, $CHCl_3$ + $SnCl_4$ , $H_2SO_4$ (+AcOH) (406)
$C_{20}H_{18}N_2O_2$	1, 2-Diketo-5-acetyl-3-phenyl-4-methyl- $\Delta^3$ -cyclopentene phenylhydrazone: EtOH (513)	$C_{21}H_{18}O_6S$	<i>o</i> -Cresolsulfonephthalein: $H_2O$ , acid, alk. (484†)
$C_{20}H_{18}N_2O_7$	Berberine nitrate: $H_2O$ (140)	$C_{21}H_{18}S_3$	Trithiobenzaldehyde (534)
$C_{20}H_{18}N_4$	Phenylglyoxalosazone (45)	$C_{21}H_{20}ClN_5O$	Antipyrine-4-azonaphthylamine hydrochloride: EtOH (478)
$C_{20}H_{18}N_4O$	<i>p</i> -Acetylbenzeneazophenol phenylhydrazone: EtOH + NaOH (316)	$C_{21}H_{20}ClN_5O_4S$	Antipyrine-4-azo- $\beta$ -naphthylamine-6'-sulfonic acid hydrochloride: EtOH (478)
$C_{20}H_{18}O_2$	3-Methyl-4-hydroxytriphenylcarbinol (5.6)	$C_{21}H_{20}N_4$	Phenylglyoxalmethylosazone (45)
$C_{20}H_{18}O_5$	Dimethyl $\beta$ -benzoyl- $\gamma$ -phenylvinylmalonate: EtOH (92)	$C_{21}H_{20}N_4O_3$	Antipyrine-4-azobenzoylacetone: EtOH, +NaOEt (478)
$C_{20}H_{18}O_5$	Dimethyl 3-benzoyl-2-phenylcyclopropanedicarboxylate: EtOH (92)	$C_{21}H_{20}O$	Triphenylcarbinyl ethyl ether: $Et_2O$ (5.5)
$C_{20}H_{19}NO_5$	Berberine (287); EtOH (606†, 630†); $H_2O$ (630†)	$C_{21}H_{20}O_3$	<i>o</i> -Cresolbenzein: EtOH, HCl, $H_2SO_4$ , KOH (484.3)
$C_{20}H_{20}ClN_3$	Fuchsine: dil. HCl (229, 233)	$C_{21}H_{20}O_5$	Dimethyl 2-phenyl-3-methylbenzoylcyclopropanedicarboxylate: EtOH (92)
$C_{20}H_{20}N_2O_4$	<i>m</i> , <i>m'</i> , <i>p</i> , <i>p'</i> -Tetramethoxy-2, 6-diphenylpyrazine: $CHCl_3$ (635)	$C_{21}H_{20}O_6$	Dimethyl $\beta$ -anisoyl- $\gamma$ -phenylvinylmalonate: EtOH (92)
$C_{20}H_{20}O_5$	Dimethyl $\gamma$ -benzoyl- $\beta$ -phenylethylmalonate: EtOH (92)	$C_{21}H_{20}O_6$	Dimethyl 3-anisoyl-2-phenylcyclopropanedicarboxylate: EtOH (92)
$C_{20}H_{21}BrN_2O_4$	<i>m</i> , <i>m'</i> , <i>p</i> , <i>p'</i> -Tetramethoxy-2, 6-diphenylpyrazine hydrobromide: $CHCl_3$ (635)	$C_{21}H_{21}N$	Tribenzylamine: $Et_2O$ (522)
$C_{20}H_{21}ClN_2O_4$	<i>m</i> , <i>m'</i> , <i>p</i> , <i>p'</i> -Tetramethoxy-2, 6-diphenylpyrazine hydrochloride: $CHCl_3$ (635)	$C_{21}H_{21}NO_4$	Methyldihydroberberine: EtOH (630)
		$C_{21}H_{21}NO_6$	Hydrastine: EtOH (140, 287, 603†); $Et_2O$ (603†); $H_2O$ (606†)
		$C_{21}H_{21}O_4P$	Tri- <i>o</i> ( <i>p</i> )-tolyl phosphate: EtOH (522)
		$C_{21}H_{21}ClNO_4$	Methyldihydroberberine hydrochloride: EtOH (630)
		$C_{21}H_{22}N_2O_2$	Strychnine: EtOH (264)
		$C_{21}H_{22}O_5$	Dimethyl benzoylphenylpropylmalonate: EtOH (92)
		$C_{21}H_{22}O_5$	Dimethyl $\gamma$ -anisoyl- $\beta$ -phenylethylmalonate: EtOH (92)



Formula	Name, solvents and literature	Formula	Name, solvents and literature
<b>Ultra-violet and Visible.—(Continued)</b>			
$C_{11}H_{13}NO_5$	Cryptopine (137)	$C_{23}H_{20}Br_4O_4$	Bis( $\alpha$ , $\beta$ -dibromoanisylmethyl)pyrone: EtOH (+ NaOEt) (76)
$C_{11}H_{14}ClNO_4$	Heroine hydrochloride: $H_2O$ (606†)	$C_{23}H_{20}O_2$	$\alpha$ , $\gamma$ -Dibenzoyl- $\beta$ -phenylpropane: EtOH (92)
$C_{11}H_{14}ClNO_5$	Cryptopine hydrochloride (137)	$C_{23}H_{20}O_4$	Bis(anisylidenemethyl)pyrone: EtOH, AcOH (76)
$C_{11}H_{14}O_{10}$	Phlorizine (286)	$C_{23}H_{21}ClO_4$	Bis(anisylidenemethyl)pyrone hydrochloride: EtOH, $CHCl_3$ (76)
$C_{11}H_{14}NO_4$	Corybulbine: EtOH (140, 287)	$C_{23}H_{22}N_4O_5$	<i>dl</i> ( <i>d</i> and <i>l</i> )-Phenyl( <i>p</i> -dimethylaminobenzene azobenzoylaminoacetic acid: EtOH (83.4)
$C_{11}H_{14}N_2O_3$	Yohimbine: <i>v. p.</i> 360	$C_{23}H_{22}O_3$	Dimethoxycinnamylideneacetone: $H_2SO_4$ (+ AcOH) (406)
$C_{11}H_{17}NO_4$	Laudanosine (137†); EtOH (139, 141)	$C_{23}H_{23}N_5O$	Antipyrine-4-azoethyl- $\beta$ -naphthylamine: EtOH (478)
$C_{11}H_{18}N_2O_2$	Optoquinine: <i>v. p.</i> 360	$C_{23}H_{24}ClN_5O$	Antipyrine-4-azoethyl- $\beta$ -naphthylamine hydrochloride: EtOH (478)
$C_{11}H_{18}O_3$	Menthyl benzylideneacetate: $C_6H_6$ (559)	$C_{23}H_{24}N_2O$	Tetramethyldiaminofuchsone (228)
$C_{11}H_{18}O_4$	Menthyl benzylacetate: $C_6H_6$ (559)	$C_{23}H_{24}O$	Diphenylmethylenecamphor (560)
$C_{12}H_{14}$	Picene: $C_6H_6$ (323, 325)	$C_{23}H_{24}O_6$	Tetramethoxytriphenylcarbinol: $Me_2CO$ + acid (419.2)
$C_{12}H_{14}$	Dinaphthanthracene: $C_6H_6$ (323, 325)	$C_{23}H_{26}N_2O$	Camphorquinone phenylbenzylhydrazone (45)
$C_{12}H_{14}O_6$	1, 8(9)-Diacetoxynaphthacenequinone: EtOH, NaOEt, $H_2SO_4$ , $H_3BO_3$ (41)	$C_{23}H_{26}N_2O_4$	Brucine: EtOH (264)
$C_{12}H_{16}N_2$	4, 5-Diphenylpyrrolinophenazine: EtOH (512)	$C_{23}H_{26}O$	Diphenylcamphomethane (560)
$C_{12}H_{16}ClN_2$	Aminophenyl naphthophenazonium chloride: $H_2O$ (289)	$C_{23}H_{27}NO_8$	Narceine (264); EtOH (140, 287, 605, † 606†)
$C_{12}H_{17}N_2O$	2, 3-Diketo-4, 5-diphenylpyrroline phenylhydrazone: EtOH (512)	$C_{23}H_{30}O_2S_4$	Methylene fenchylxanthate (97)
$C_{12}H_{18}O_2$	Triphenylvinyl acetate: $CHCl_3$ (392)	$C_{24}H_{14}N_2O_5$	2-Nitro-6-anilino-1-hydroxynaphthacenequinone: EtOH, NaOEt, $H_2SO_4$ , $H_3BO_3$ (41)
$C_{12}H_{18}O_4$	Phenolphthalein dimethyl ether and esters: $CHCl_3$ + $SnCl_4$ , $H_2SO_4$ (465)	$C_{24}H_{15}NO_2$	1-Anilino-6-hydroxynaphthacenequinone: EtOH, NaOEt, $H_2SO_4$ , $H_3BO_3$ (41)
$C_{12}H_{18}NO_2$	Dimethylisopropylquinophthalone: EtOH (489.5)	$C_{24}H_{17}Cl_2N_2$	Phenylaminochlorophenazonium phenylchloride (16)
$C_{12}H_{18}NO_5S_2$	Dimethylisopropylquinophthalonesulfonic acid, Na salt: $H_2O$ (489.5)	$C_{24}H_{18}N_4O_2$	Bis(benzeneazo)diphenol: EtOH (550)
$C_{12}H_{19}N_2O$	Phenyl styryl ketone phenylsemicarbazone: EtOH (+ NaOEt) (296)	$C_{24}H_{20}O_6$	Tribenzoin: EtOH (522)
$C_{12}H_{21}ClO_5$	Trimethoxytriphenylcarbinyl chloride: (419.2)	$C_{24}H_{22}O_6$	Bis(anisylidenemethyl)pyrone formate: EtOH (76)
$C_{12}H_{22}O_2$	Trianisylmethane: EtOH (13)	$C_{24}H_{26}O_6$	Pentamethoxytriphenylcarbinol: $Me_2CO$ + acid (419.2)
$C_{12}H_{22}O_4$	Trianisylcarbinol: $H_2SO_4$ (13, 406)	$C_{24}H_{27}NOS_2$	1, 2-Diphenyl-3-fenchyl-imidoxanthogenide (97)
$C_{12}H_{22}O_4$	Trimethoxytriphenylcarbinol: $H_2O$ + $Me_2CO$ + acid (419.2)	$C_{24}H_{30}OS_2$	Diphenylmethyl menthylxanthate: EtOH (97)
$C_{12}H_{22}O_6$	Diethyl $\alpha$ ( $\beta$ , $\gamma$ )-dibenzoylsuccinate: EtOH (234)	$C_{24}H_{30}ClN_2O_2$	Eucupinotoxine hydrochloride: <i>v. p.</i> 360
$C_{12}H_{23}NO_7$	Gnoscopine (140†)	$C_{24}H_{30}Cl_2N_2O_2$	Eucupine dihydrochloride: <i>v. p.</i> 360
$C_{12}H_{23}NO_7$	Narcotine: EtOH (140, 264, 287, 603†, 605†, 606†); $Et_2O$ (603†)	$C_{25}H_{24}N_4O$	2, 3-Bis( <i>p</i> -dimethylaminoanilo)- $\alpha$ -hydrindone: EtOH (516)
$C_{12}H_{23}NO_8$	Hydroxynarcotine: EtOH + AcOH (264)	$C_{25}H_{27}NO_7$	Tetraacetylmorphine: EtOH (279)
$C_{12}H_{24}N_2O$	Camphorquinone diphenylhydrazone (45)	$C_{25}H_{28}O_7$	2, 4, 2', 4', 2'', 4''-Hexamethoxytriphenylcarbinol (419.2)
$C_{12}H_{24}NO_5$	Diacetylcodeine: EtOH (264)	$C_{25}H_{30}O_2$	Menthyl $\alpha$ ( $\beta$ )-phenylcinnamate (560)
$C_{12}H_{24}N_2O_4$	Dehydrocorydaline nitrate: $H_2O$ (140, 287)	$C_{25}H_{30}O_3$	Menthyl benzoylphenylacetate: $C_6H_6$ (559)
$C_{12}H_{27}NO_4$	Corydaline (137†); EtOH (140, 287)	$C_{25}H_{31}NO$	Phthalophenone anilide (500)
$C_{12}H_{28}O_2S_2$	Fenchylxanthic acid thioanhydride (97)	$C_{25}H_{30}$	Tetraphenylethylene: $CHCl_3$ (393)
$C_{12}H_{28}O_2S_2$	Bornylxanthic acid thioanhydride: EtOH (97)	$C_{25}H_{30}O$	$\beta$ -Benzopinacolin: $CHCl_3$ (392)
$C_{12}H_{28}O_2S_4$	Bornyl dixanthogenide: EtOH (97)	$C_{25}H_{32}$	Tetraphenylethane: $CHCl_3$ (393)
$C_{12}H_{28}O_2S_4$	Fenchyldixanthogenide (97)	$C_{25}H_{32}N_4$	Benzilosazone (45)
$C_{12}H_{30}O_2$	Behenolic acid (423)	$C_{25}H_{32}N_4O_2$	Bis(toluenazo)diphenol: EtOH (550)
$C_{12}H_{30}O_3$	Erucic acid (423, 424)	$C_{25}H_{34}N_2O_4S$	Benzylideneaniline sulfate (337)
$C_{12}H_{30}O_3$	Isoerucic acid (424)	$C_{25}H_{30}O_3$	Menthyl benzylidenebenzoylacetate: $C_6H_6$ (559)
$C_{12}H_{30}O_3$	Brassicic acid (424)	$C_{27}H_{34}O_2$	Menthyl diphenylmethylacetate: $C_6H_6$ (559)
$C_{12}H_{30}N_2O_2$	<i>p</i> -Benzoylbenzeneazo- $\alpha$ ( $\beta$ )-naphthol: EtOH (+ NaOH) (316)	$C_{28}H_{19}Cl_2N_2$	Naphthylaminochlorophenylphenazonium hydrochloride (16)
$C_{12}H_{30}O_2$	1, 3-Dibenzoyl-2-phenylcyclopropene: EtOH (92)	$C_{28}H_{28}AsI$	Tetrabenzylarsonium iodide: $H_2O$ , $CHCl_3$ (242)
$C_{12}H_{37}N_2$	4-Phenyl-5, <i>p</i> -tolylpyrrolinophenazine: EtOH (512)	$C_{28}H_{34}O_2$	Menthyl $\alpha$ -styrylbenzoylacetate (559)
$C_{12}H_{38}N_4O_5$	Benzeneazoacetylcarbonylcoumaranone phenylhydrazone: EtOH (457)		
$C_{12}H_{38}O_2$	1, 3-Dibenzoyl-2-phenylcyclopropane: EtOH (92)		
$C_{12}H_{38}N_2O$	2, 3-Diketo-4-phenyl-5, <i>p</i> -tolylpyrroline phenylhydrazone: EtOH (512)		



Formula	Name, solvents and literature
<b>Ultra-violet and Visible.—(Continued)</b>	
$C_{28}H_{36}N_2O_4$	Psychotrine (137)
$C_{28}H_{36}N_2O_4$	Cephaeline (137)
$C_{29}H_{40}N_2O_4$	Emetine (137)
$C_{30}H_{34}OS_2$	Triphenylmethyl menthylxanthate: EtOH (97)
$C_{30}H_{62}O$	Melissyl alcohol (438†)
$C_{32}H_{21}N_5O_4S_2$	Tetraphenyldithiopurpuric acid: MeOH (402)
$C_{32}H_{24}$	Tetraphenylquinonodimethane: EtOH, Et <sub>2</sub> O (293)
$C_{32}H_{24}N_6O_6S_2$	Congo red (232); Na salt: acid, alk. (232)
$C_{32}H_{26}$	Tetraphenyl- <i>p</i> -xylene (410)
$C_{32}H_{49}NO_9$	Veratrine: EtOH (264)
$C_{33}H_{26}N_2O$	Benzoyldianilinostilbene: EtOH (155)
$C_{34}H_{24}Cl_2N_4$	Phenylaminonaphthylaminochlorophenazo- nium phenylchloride (16)
$C_{34}H_{25}ClN_4$	Phenylaminonaphthylaminophenazonium phenylchloride (16)
$C_{34}H_{33}ClN_4O_4$	Mesoporphyrin hydrochloride (433†); EtOH (171†); cf. p. 360
$C_{34}H_{47}NO_{11}$	Aconitine (264)
$C_{34}H_{48}N_2O_{10}S$	Atropine sulfate: H <sub>2</sub> O (95†); cf. p. 360
$C_{34}H_{48}N_2O_{10}S$	Hyosciamine sulfate: H <sub>2</sub> O (95†); cf. p. 360
$C_{35}H_{36}N_4O_5$	Phyllocyanine (433†)
$C_{35}H_{56}O_{14}$	Digitalin: EtOH (264)
$C_{36}H_{40}N_4O_6$	Hematoporphyrin dimethyl ether (171†); cf. p. 360
$C_{38}H_{30}$	Hexaphenylethane (13)
$C_{40}H_{26}$	Tetranaphthyl (323†)
$C_{40}H_{50}N_4O_8S$	Quinine sulfate: v. p. 360
$C_{40}H_{50}N_4O_8S$	Quinidine sulfate: v. p. 360
$C_{40}H_{54}N_4O_8S$	Hydroquinine sulfate: v. p. 360
$C_{40}H_{56}$	Carotin: Et <sub>2</sub> O (131†)
$C_{40}H_{56}O_2$	Xanthophyllin: Et <sub>2</sub> O (131†)
$C_{42}H_{54}N_4O_8S$	Methylquinine sulfate: v. p. 360
$C_{54}H_{92}N_2O_{19}$	Solanine: EtOH (264)

#### ORGANIC SUBSTANCES OF MIXED OR UNKNOWN COMPOSITION. NAME, SOLVENT AND LITERA- TURE REFERENCE

Albumin (265).  
 Albuminoids (129).  
 Allochlorophyllan: CHCl<sub>3</sub> (339).  
 Amino acids (129,† 357†)  
 Blood sera (381†).  
 Cadaverine extract; v. p. 359  
 Casein (122,† 265†).  
 Chlorophyll (205,† 206†); Et<sub>2</sub>O (130†).  
 Chlorophyllan: CHCl<sub>3</sub> (339).  
 Hematine: acid, alk. (171†); cf. p. 360  
 Hematoporphyrin (433†).  
 Hematoporphyrin hydrochloride: EtOH, H<sub>2</sub>O (171†).  
 Hemin, α and β-bromo-derivatives: EtOH, H<sub>2</sub>O (171†), cf. p.  
 360  
 α-Hemin: EtOH, H<sub>2</sub>O (171,† 433†); cf. p. 360  
 Hemoglobin derivatives: H<sub>2</sub>O (481†).  
 Hemoglobin, reduced (258†).  
 Hemoglobin, oxy- (129,† 258†); H<sub>2</sub>O (433,† 480,† 481†).  
 Methemoglobin: H<sub>2</sub>O(+Na<sub>2</sub>CO<sub>3</sub>) (257†).  
 Neochlorophyllan: CHCl<sub>3</sub> (339)  
 Nucleic acid (122)  
 Nucleic acid deriv. (129†).  
 Petroleum, crude oils and products of refining (645.1†).  
 Phycocyan: H<sub>2</sub>O (625.5).

Phycoerythrin: H<sub>2</sub>O (625.5).  
 Phylloerythrin (433†).  
 Polypeptides (di- and tri-peptides) (357†).  
 Starch (from maize) (265†).

#### LITERATURE

(For a key to the periodicals see end of volume)

- (1) Abney and Festing, 62, 172: 887; 81. (1.5) Acly and French, 1, 49: 847; 27.
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## QUANTITATIVE DETERMINATION OF ULTRA-VIOLET ABSORPTION SPECTRA IN SOLUTIONS OF ORGANIC SUBSTANCES

VICTOR HENRI

## NOMENCLATURE

- $J_0$  (resp.  $J$ ) Intensity of the incident (resp. emergent) ray.  
 $\lambda$  (resp.  $\lambda_0$ ) Wave-length of the light in the medium (resp. in *vacuo*).  $\lambda/\lambda_0 = 1/n_\lambda$ .  
 $l$  Length of path in the medium.  
 (1)  $J = J_0 e^{-\mu l}$   $\mu$  is the absorption coefficient.  
 (2)  $J = J_0 r^l$   $r$  is the transmission coefficient.  
 (3)  $J = J_0 10^{-Kl}$   $K$  is the extinction coefficient.  
 (4)  $J = J_0 10^{-\epsilon c l}$   $\epsilon$  is the molecular extinction coefficient.  
 (5)  $J = J_0 e^{-\frac{4\pi\kappa l}{\lambda}}$   $\kappa$  is the absorption index.

The above coefficients are connected by the following relations:

$$\begin{aligned}\mu &= 2.3026\epsilon \\ -\log_{10} r &= \epsilon c \\ \kappa &= 0.7956 \mu \lambda \cdot (\lambda \text{ in cm}) \\ \kappa &= 1.832 \epsilon \lambda \cdot (\lambda \text{ in cm})\end{aligned}$$

$\epsilon$	$\log_{10} \epsilon$	$\mu$	$\kappa/\lambda$	$r$	$d$
0.01	-2	0.023026	0.01832	0.9773	100 cm
0.1	-1	0.23026	0.1832	0.7943	10 cm
1	0	2.3026	1.832	0.1	1 cm
10	+1	23.026	18.32	$10^{-10}$	0.1 cm
100	+2	230.26	183.2	$10^{-100}$	0.01 cm
1 000	+3	2 302.6	1 832	$10^{-1 000}$	0.001 cm
10 000	+4	23 026	18 320	$10^{-10 000}$	0.0001 cm
100 000	+5	230 260	183 200	$10^{-100 000}$	0.00001 cm

In the above table  $d$  represents for a normal solution ( $c = 1$ ) the path length in which 90 % of the incident light is absorbed. It is called the "active region" ("l'épaisseur active") since it represents the layer within which photochemical reactions occur.

## DESCRIPTION OF FIGURES

The figures are drawn to the same scale to facilitate comparison. They are based upon the best data recorded in the literature and many of them have been checked in the author's laboratory.

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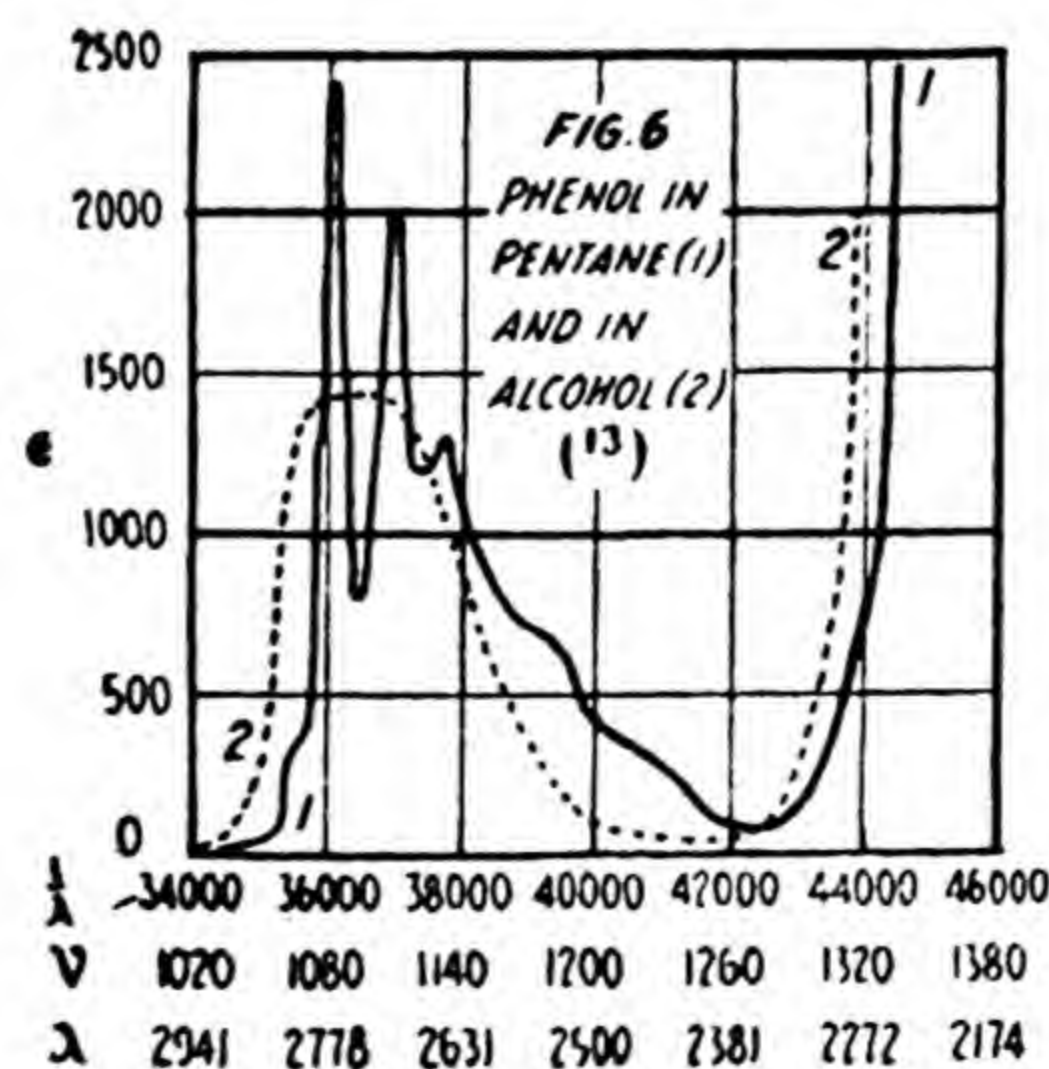
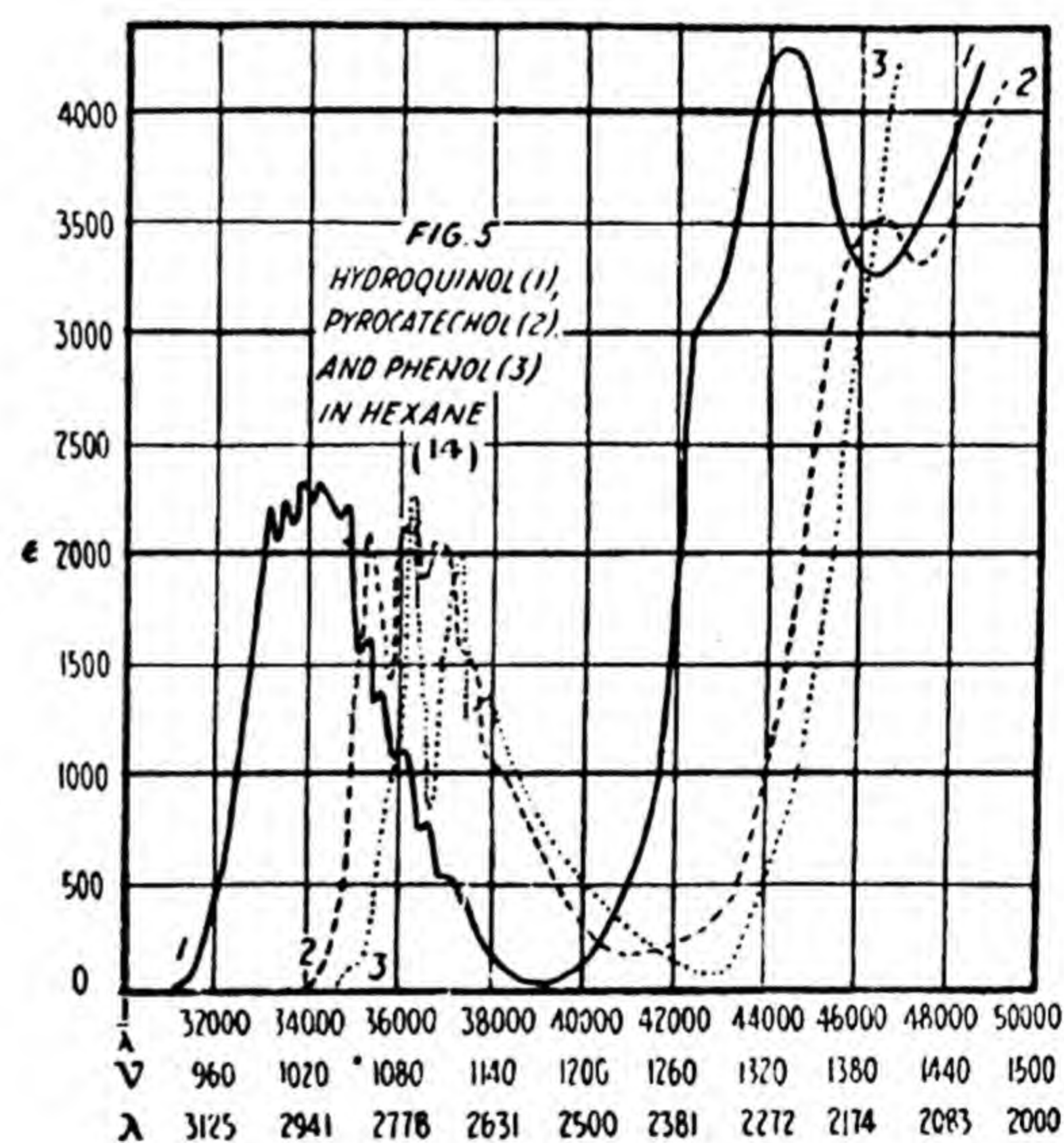
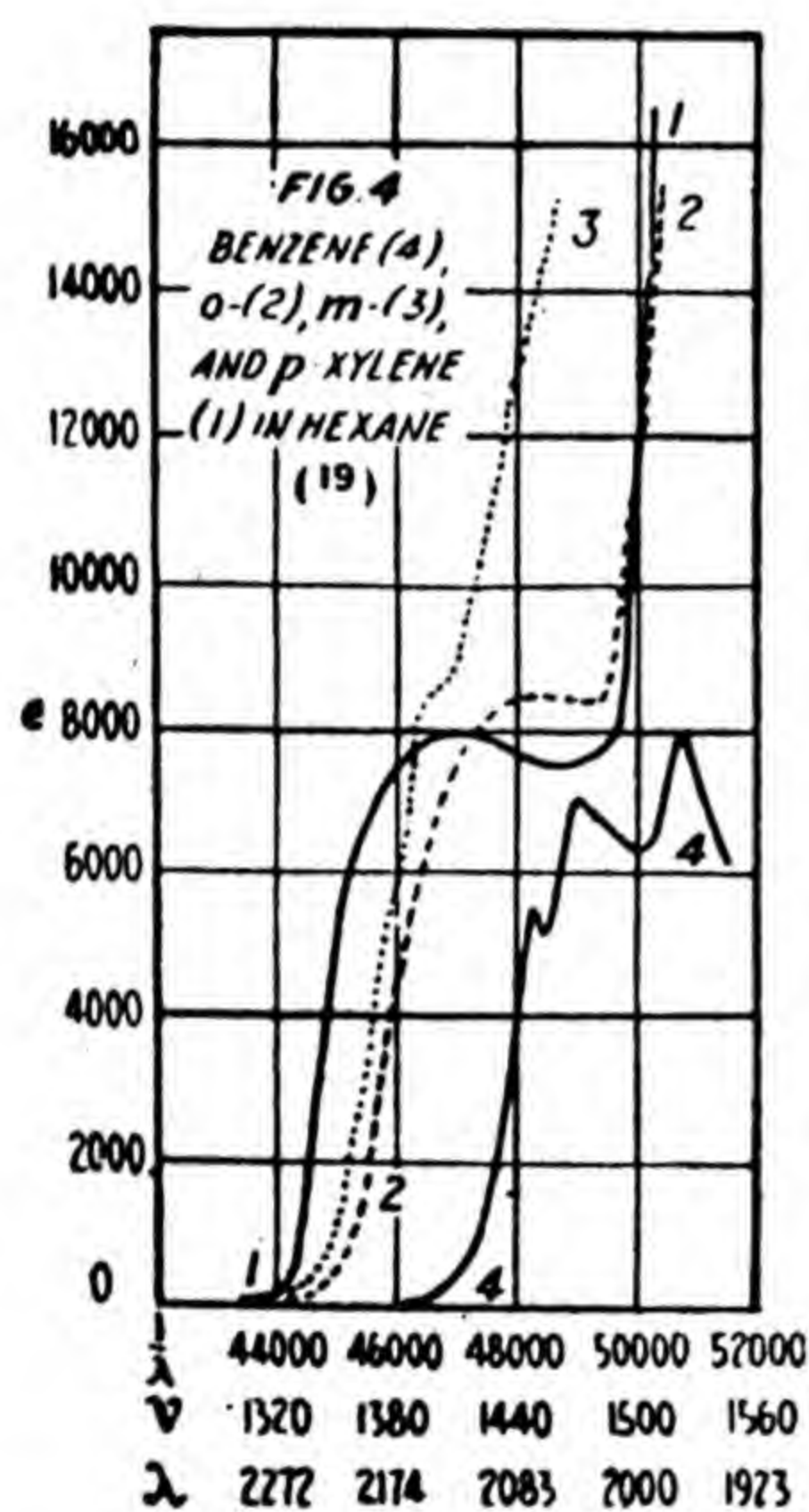
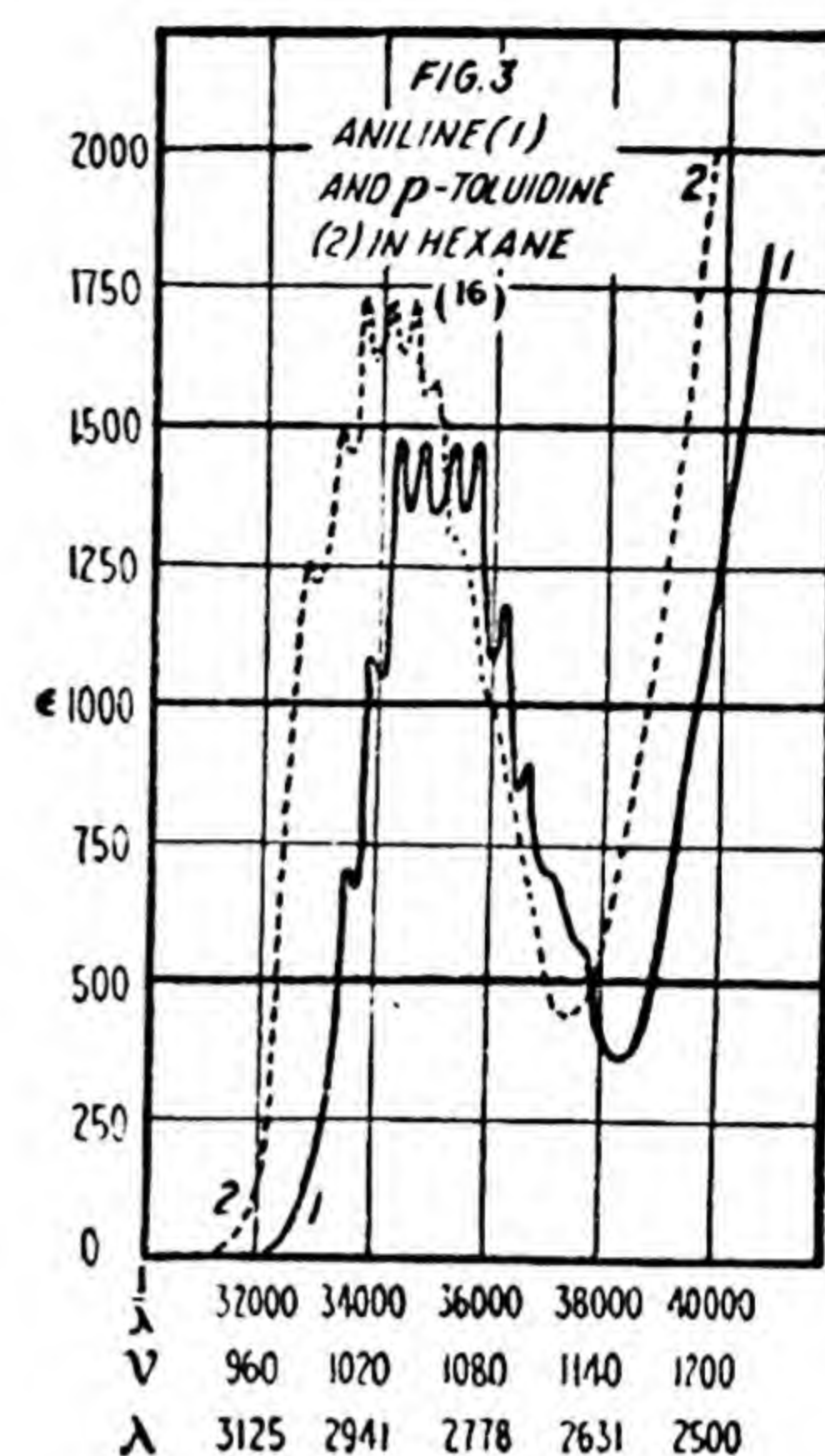
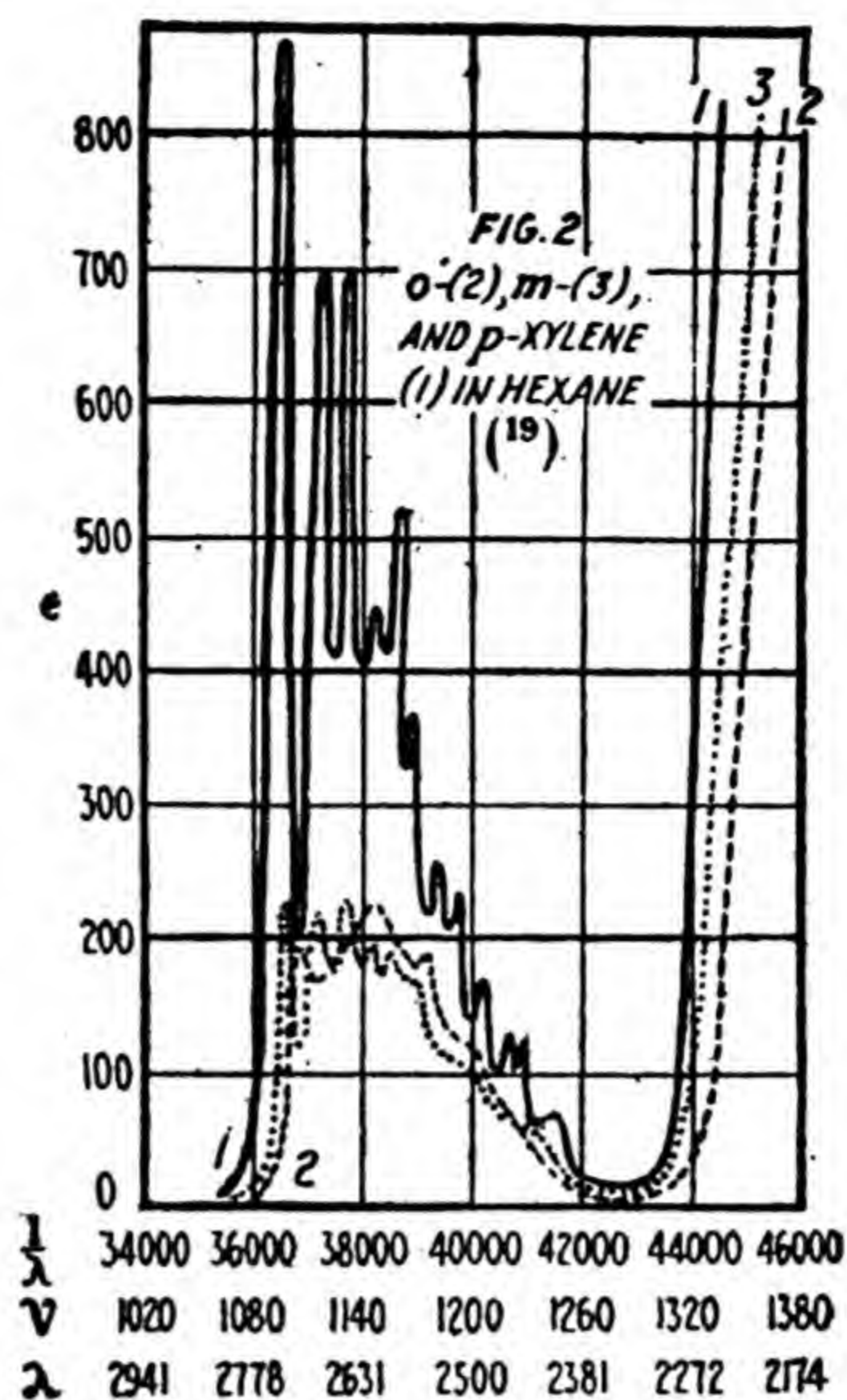
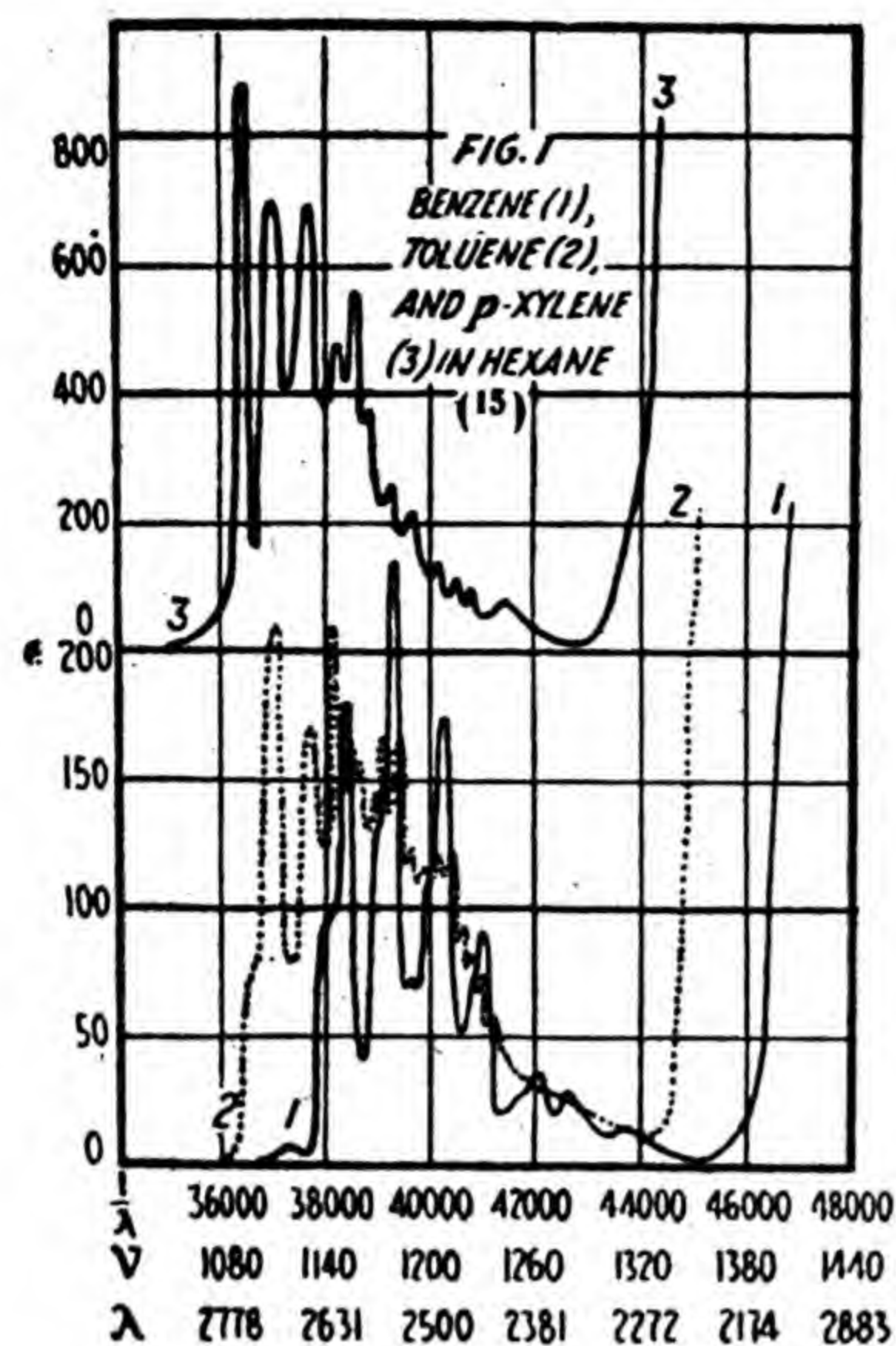
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## LITERATURE

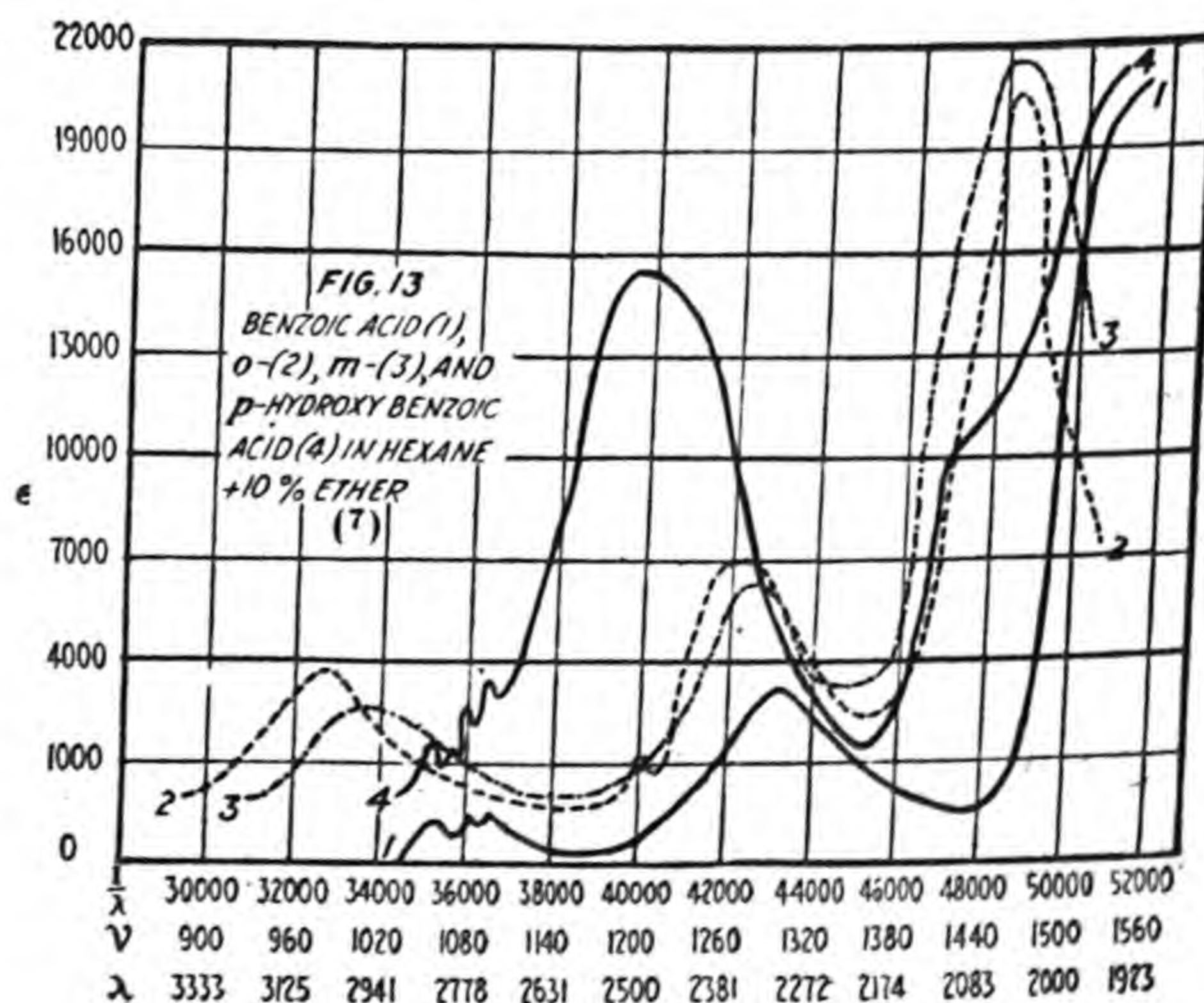
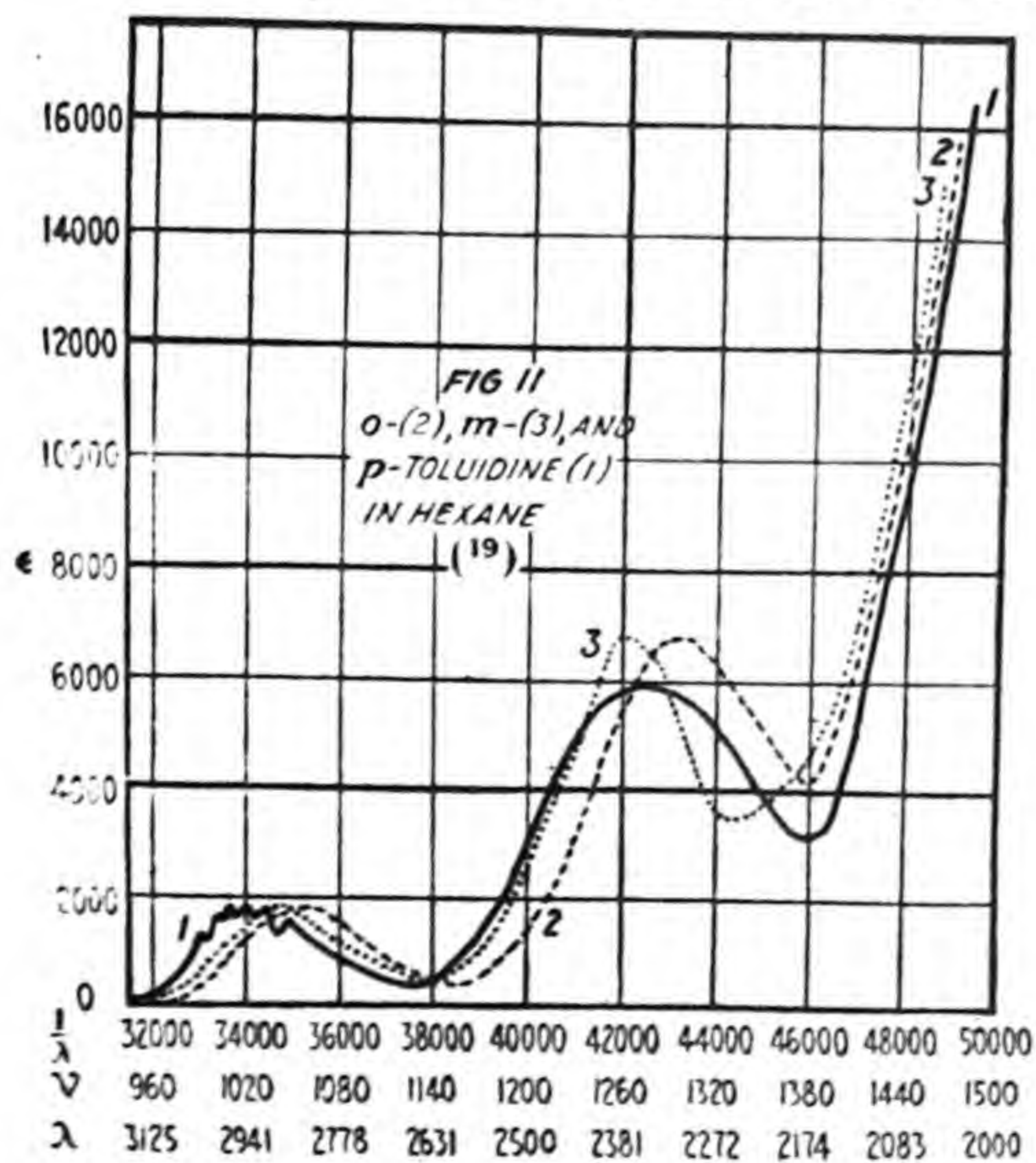
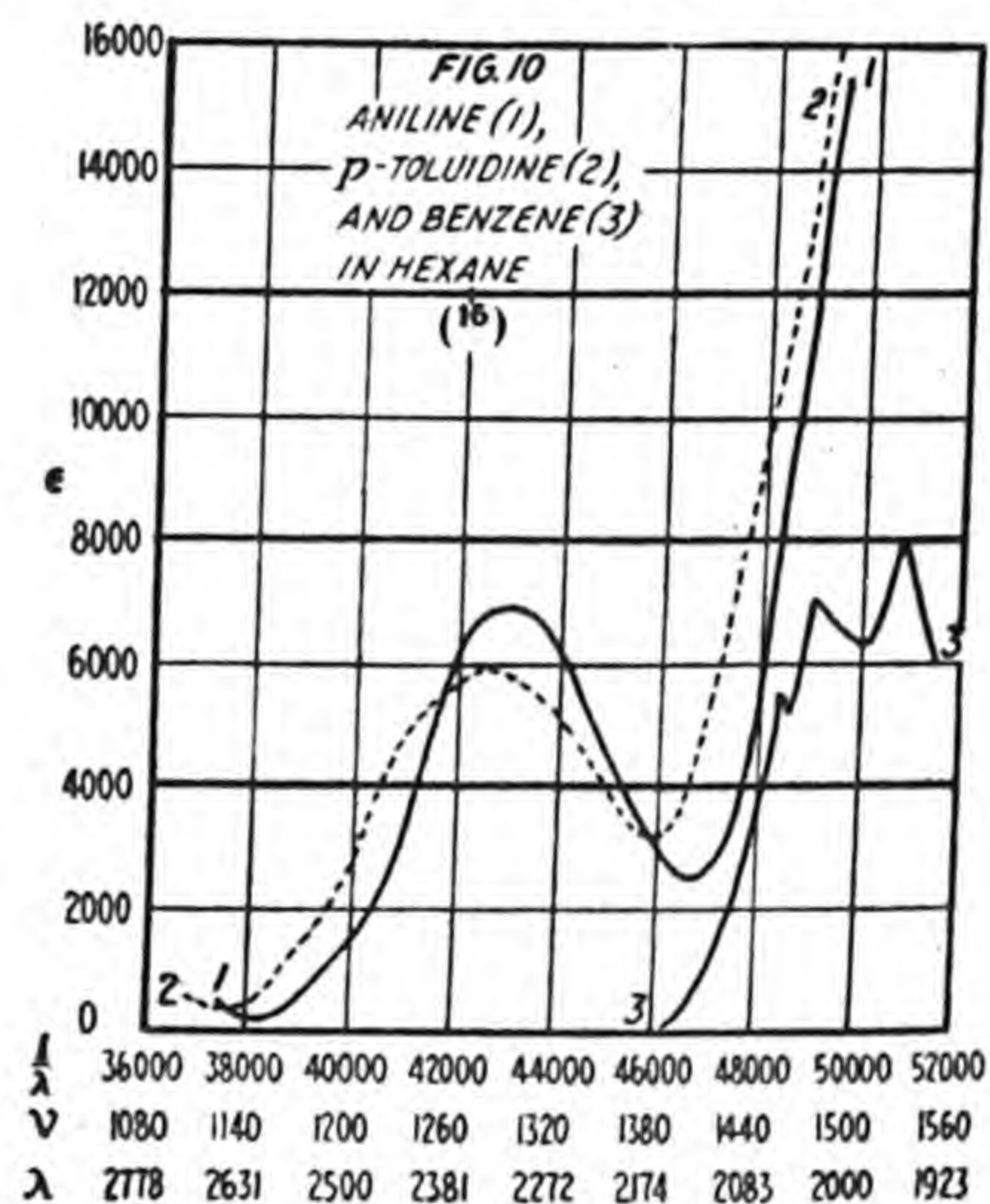
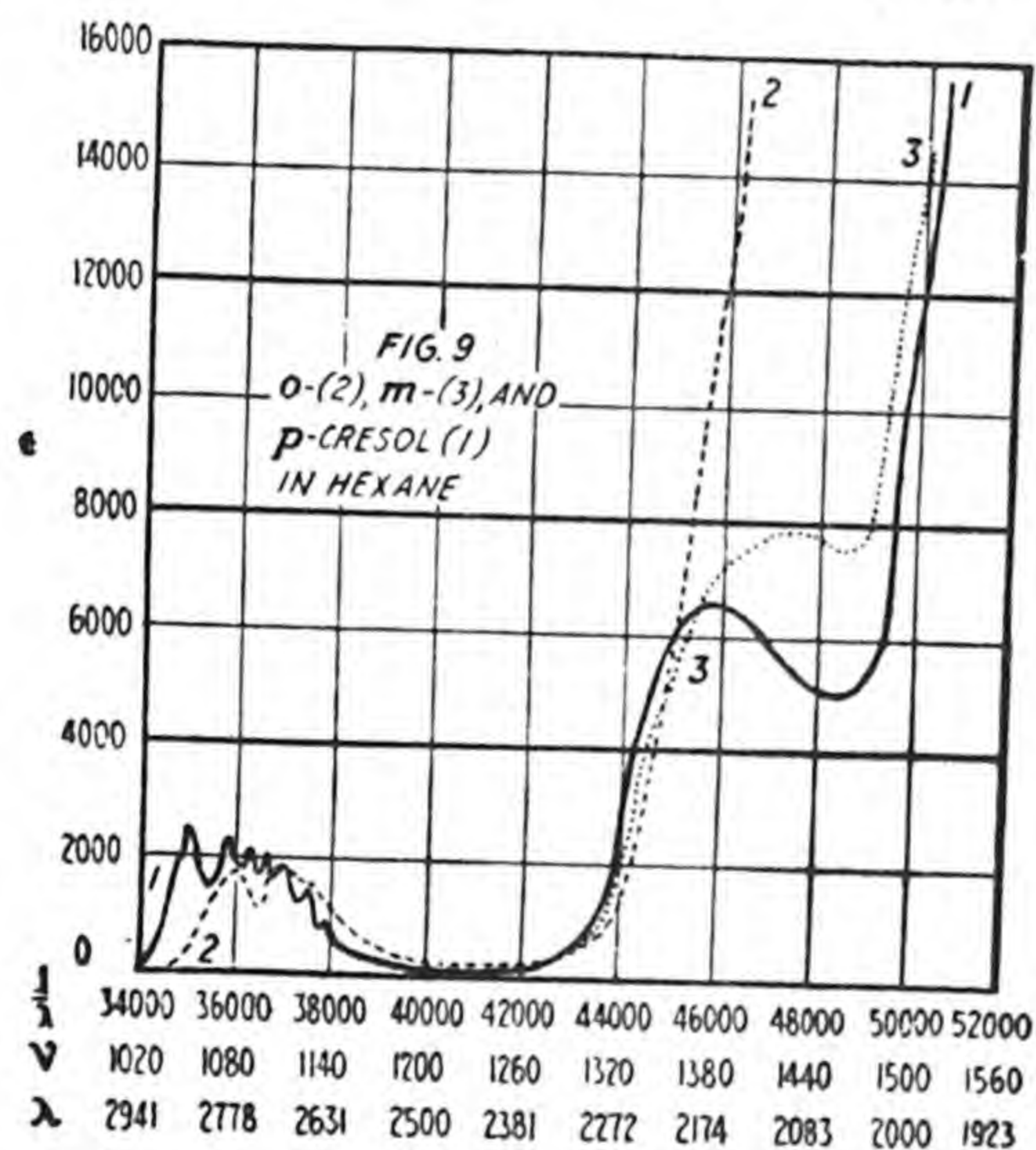
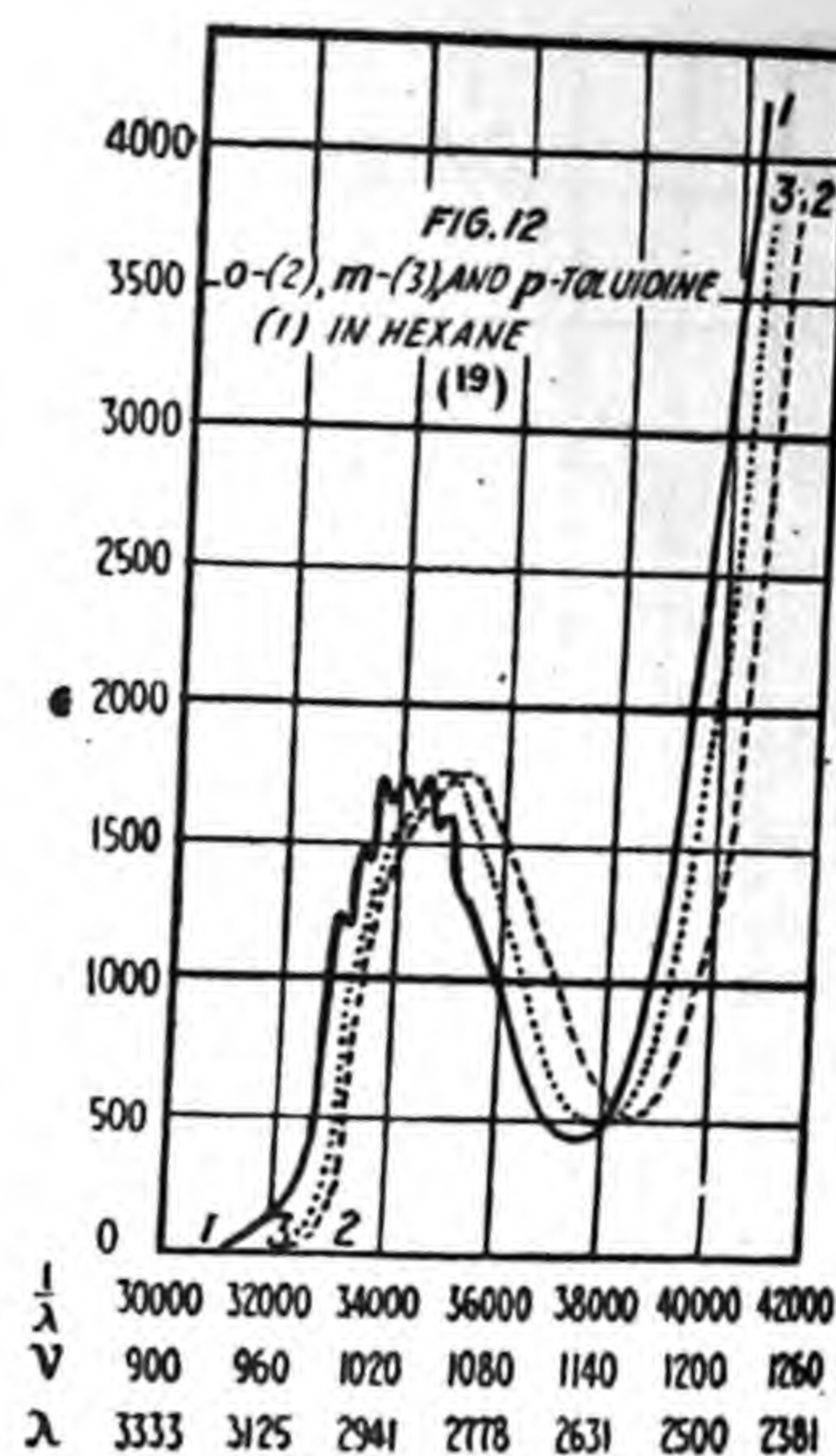
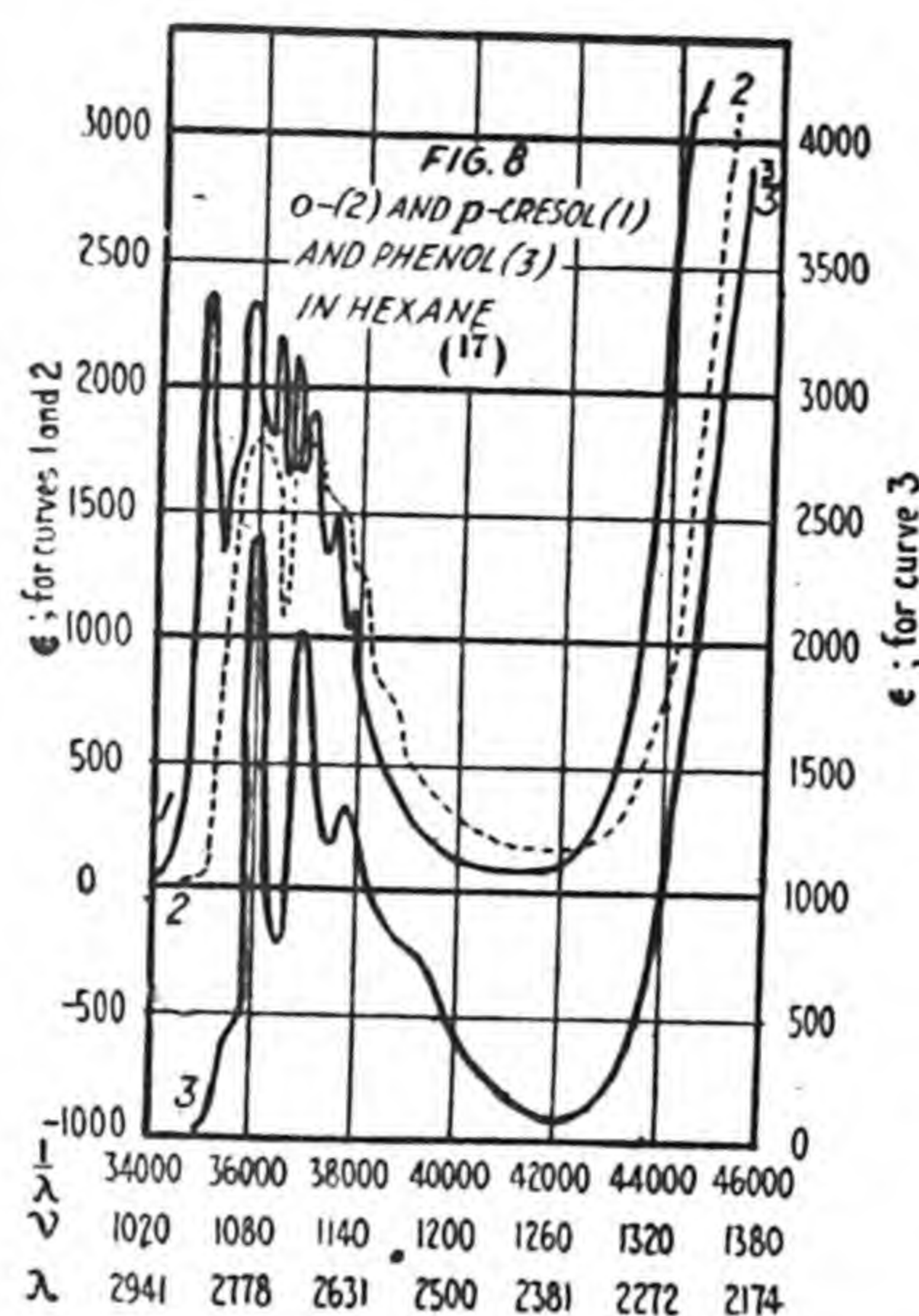
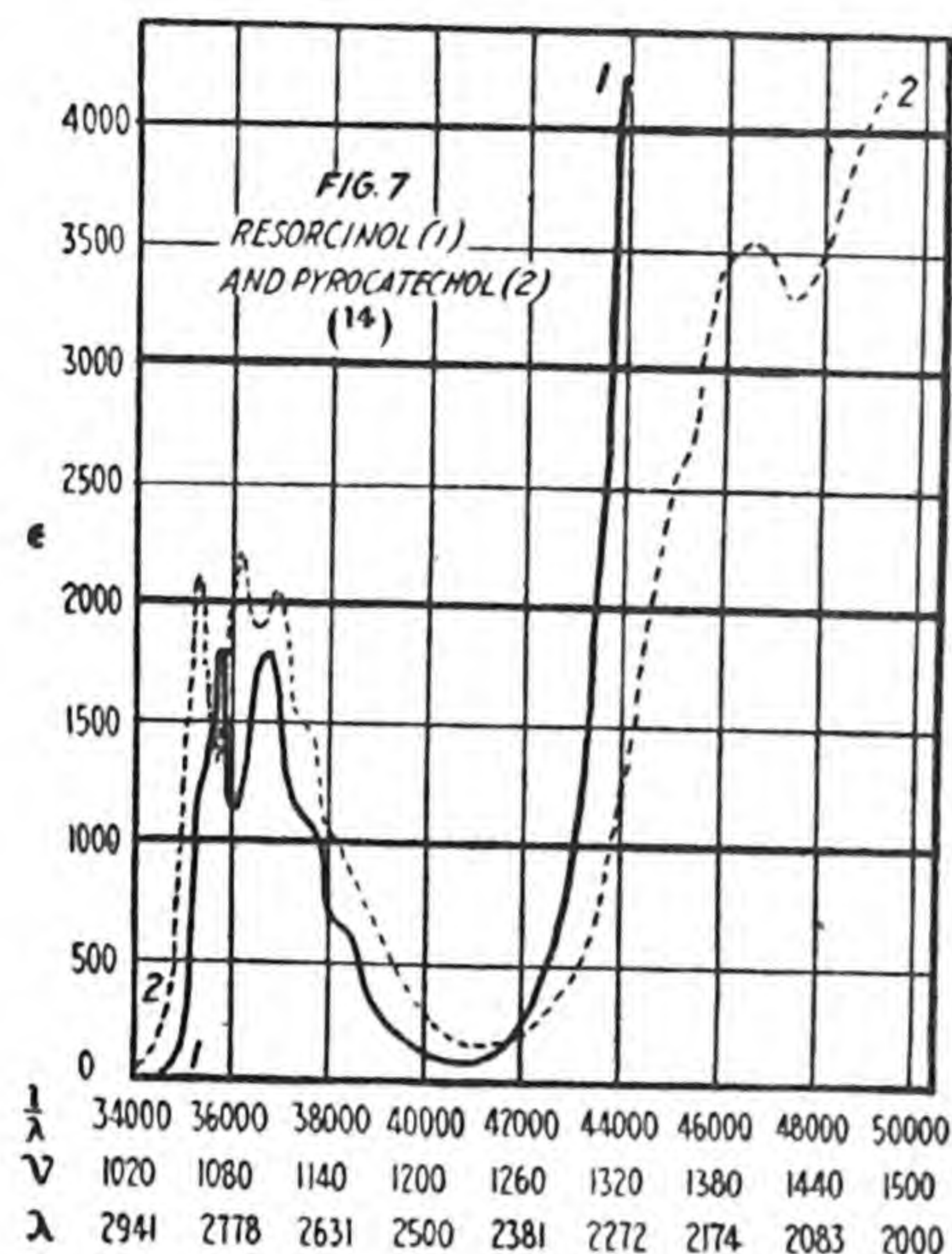
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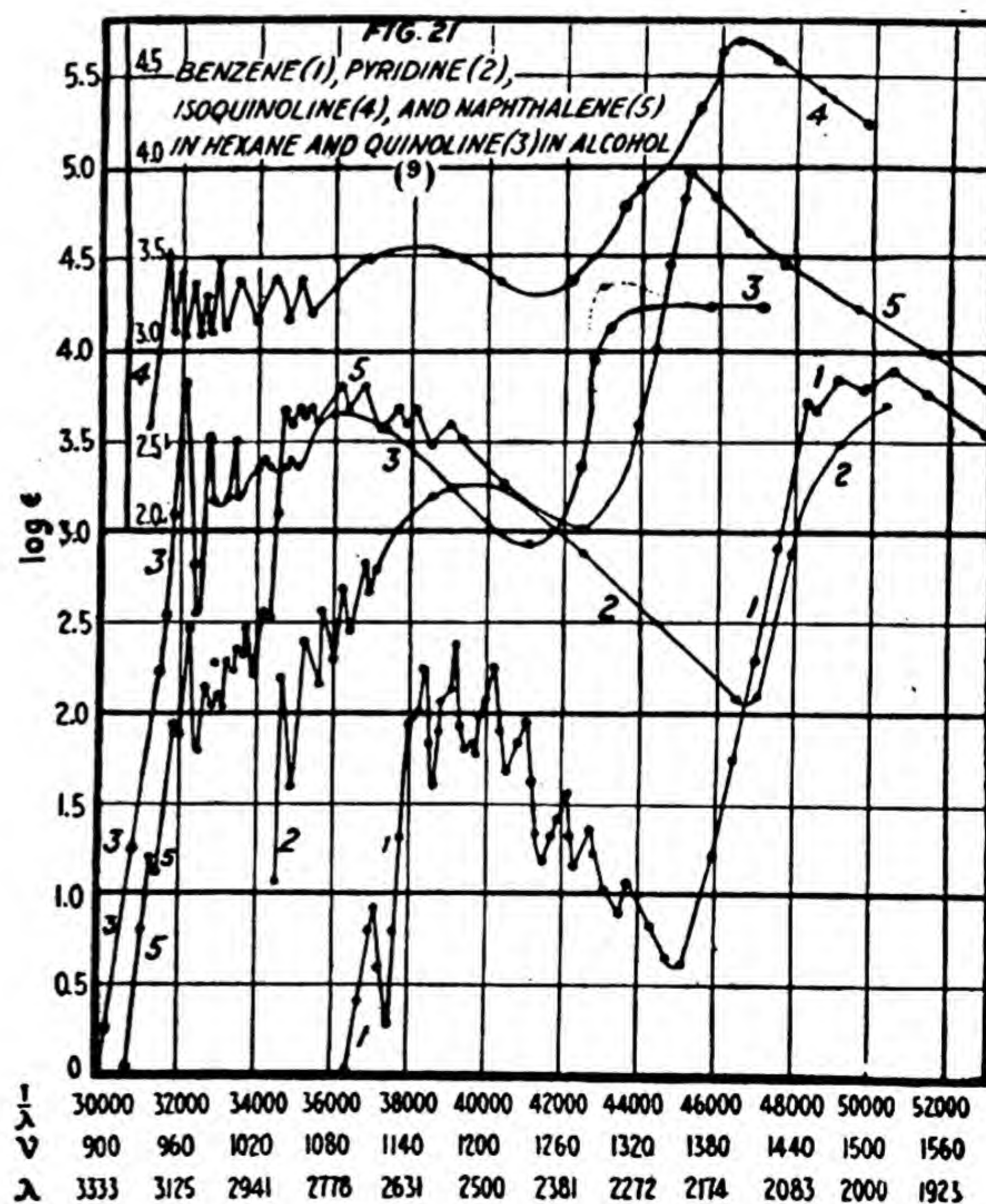
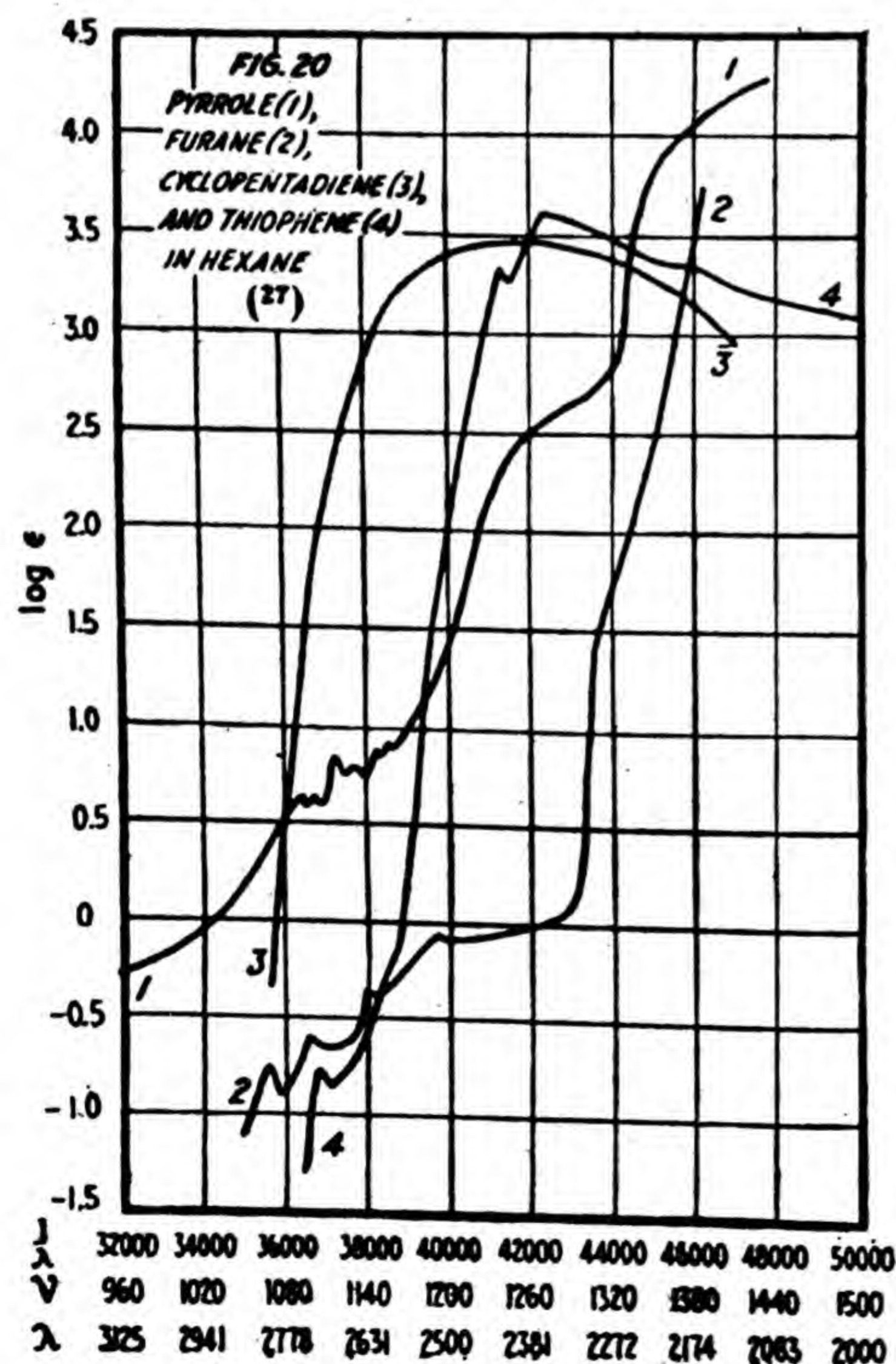
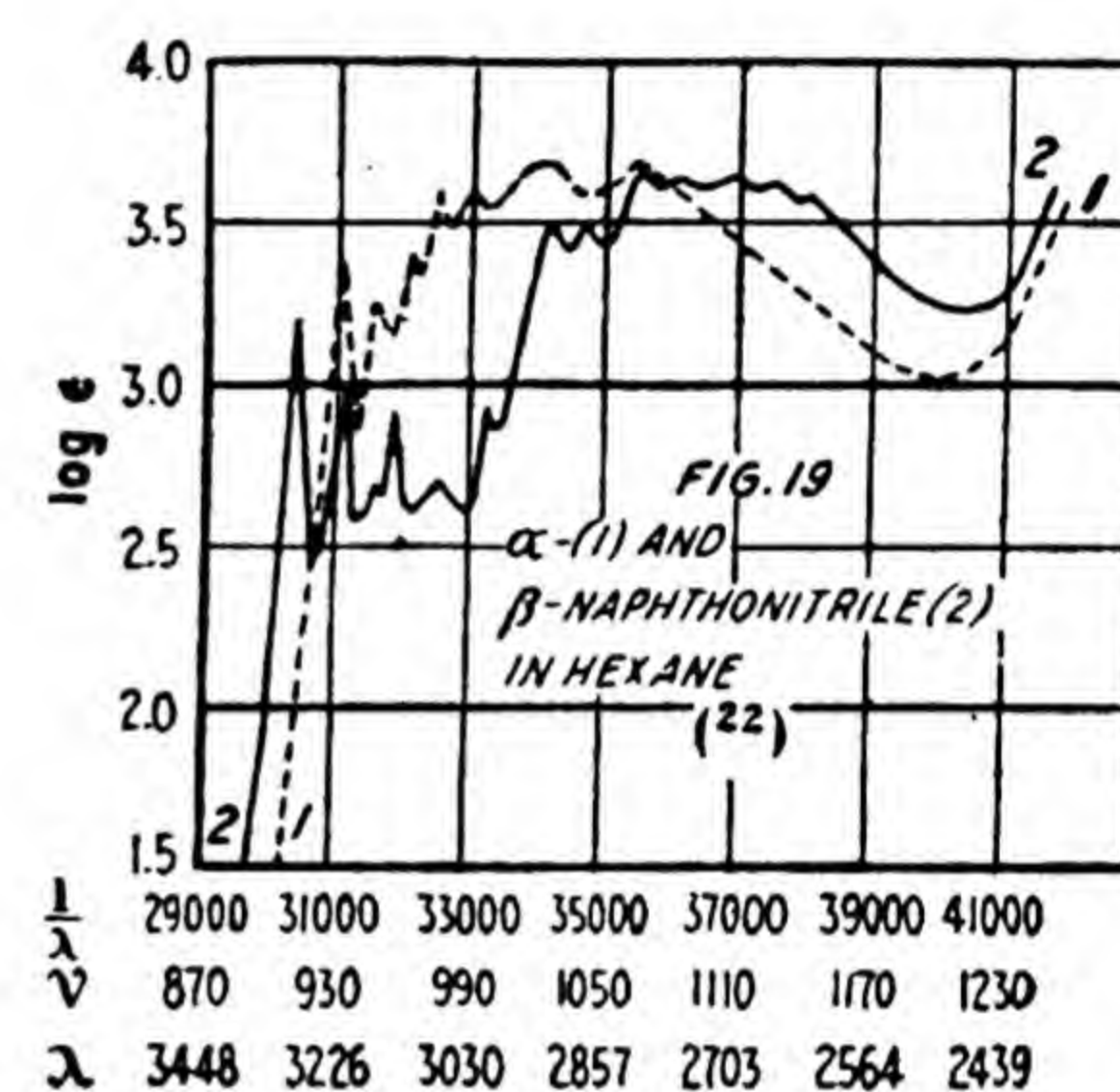
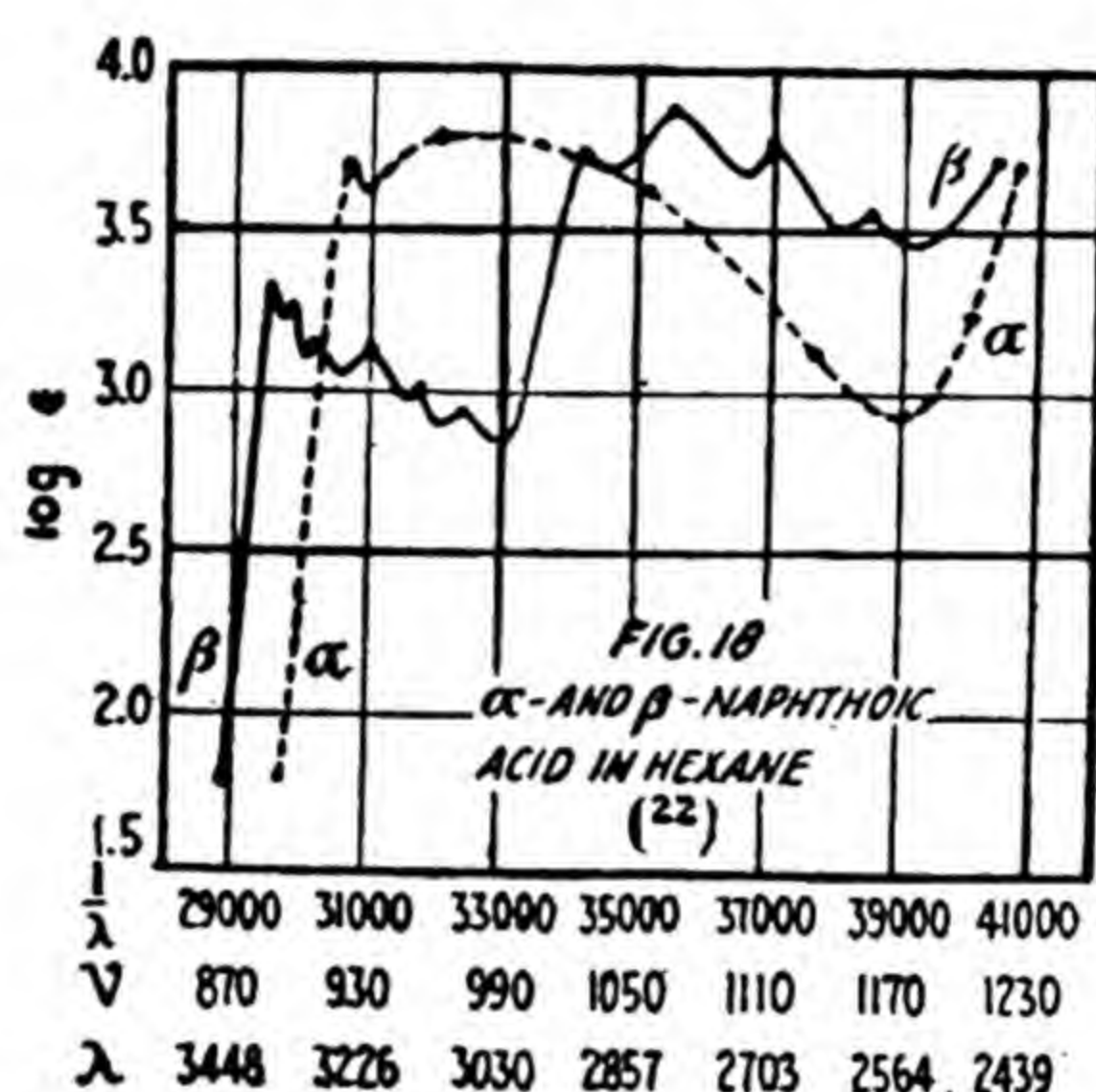
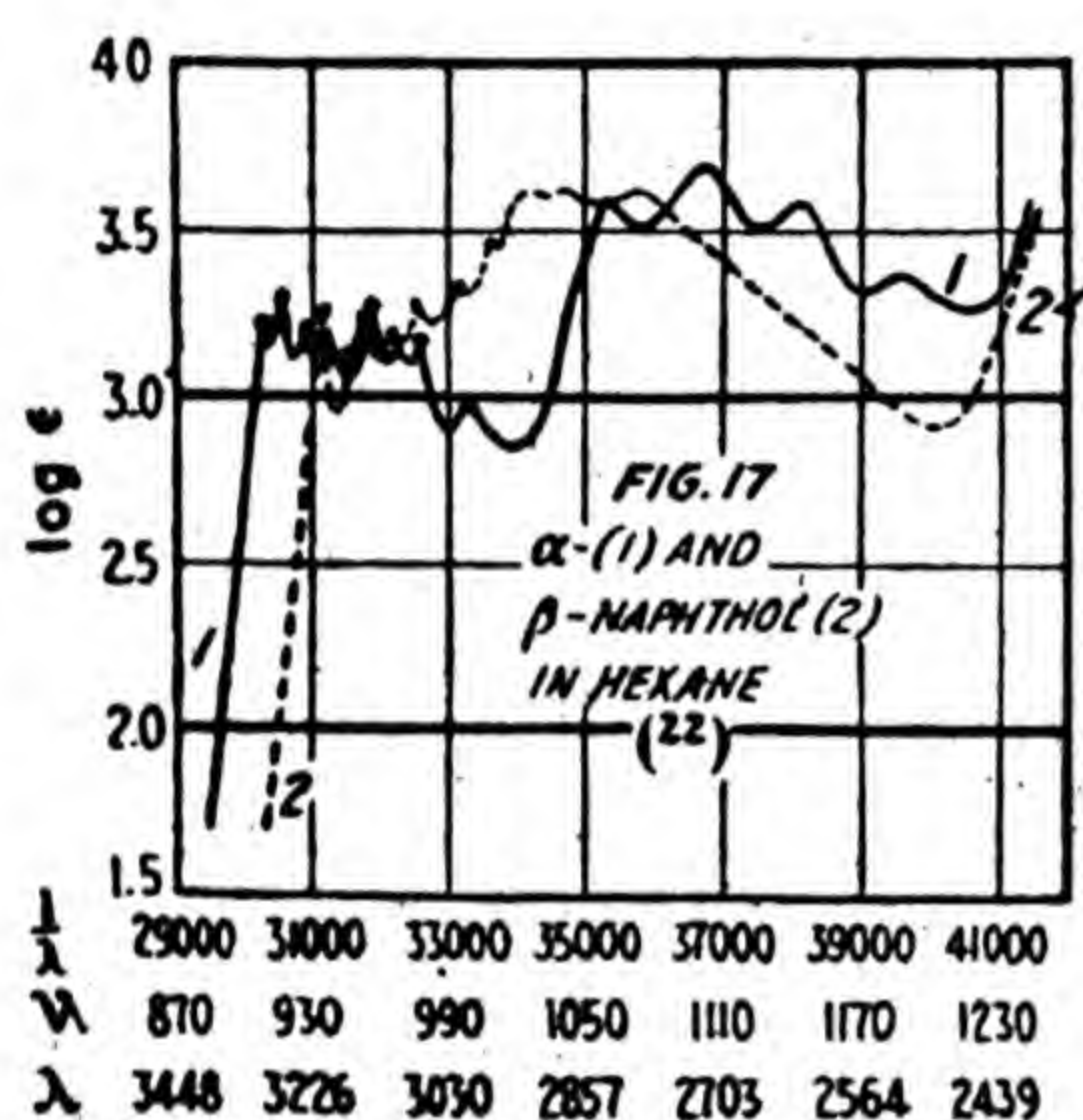
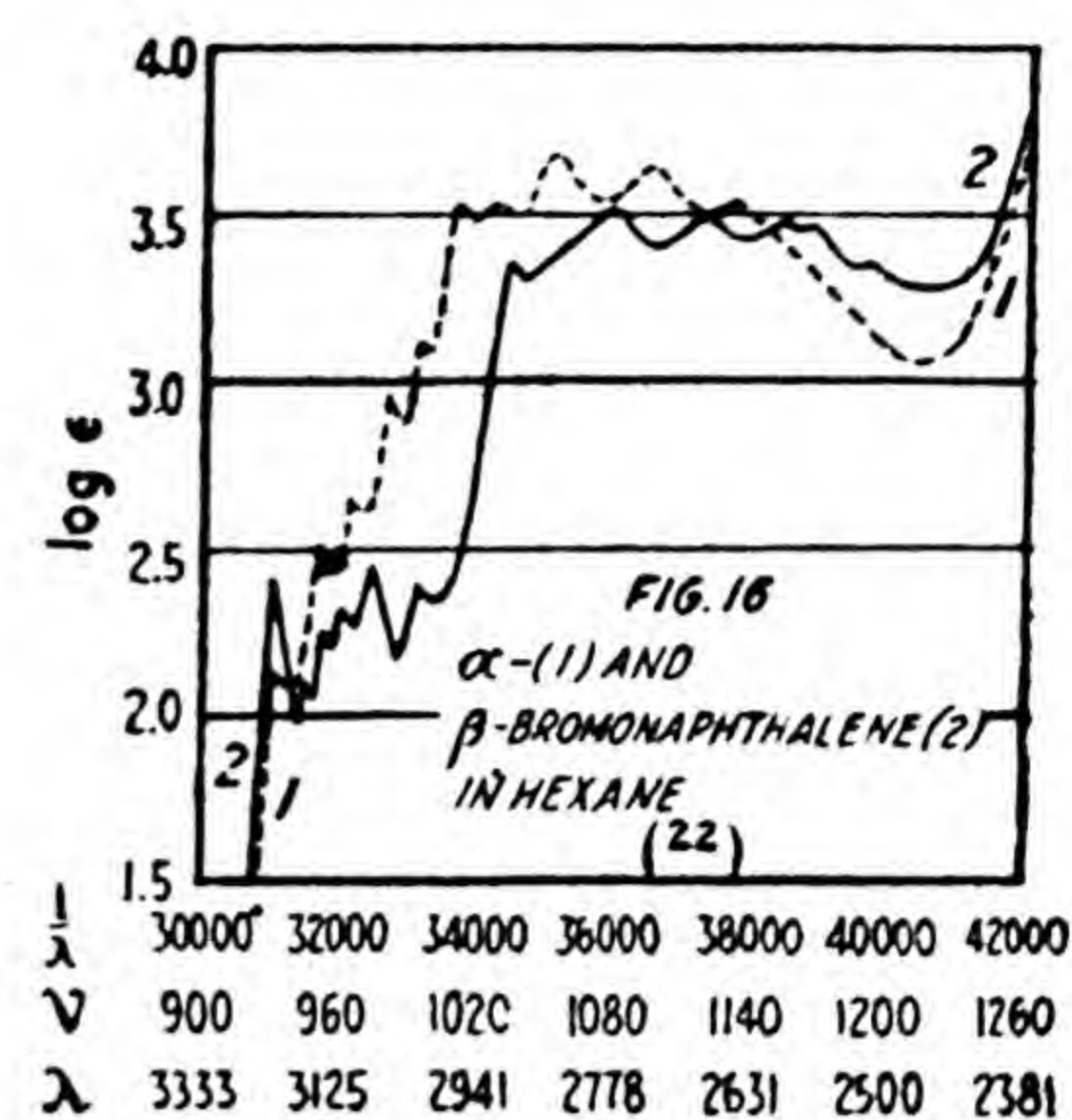
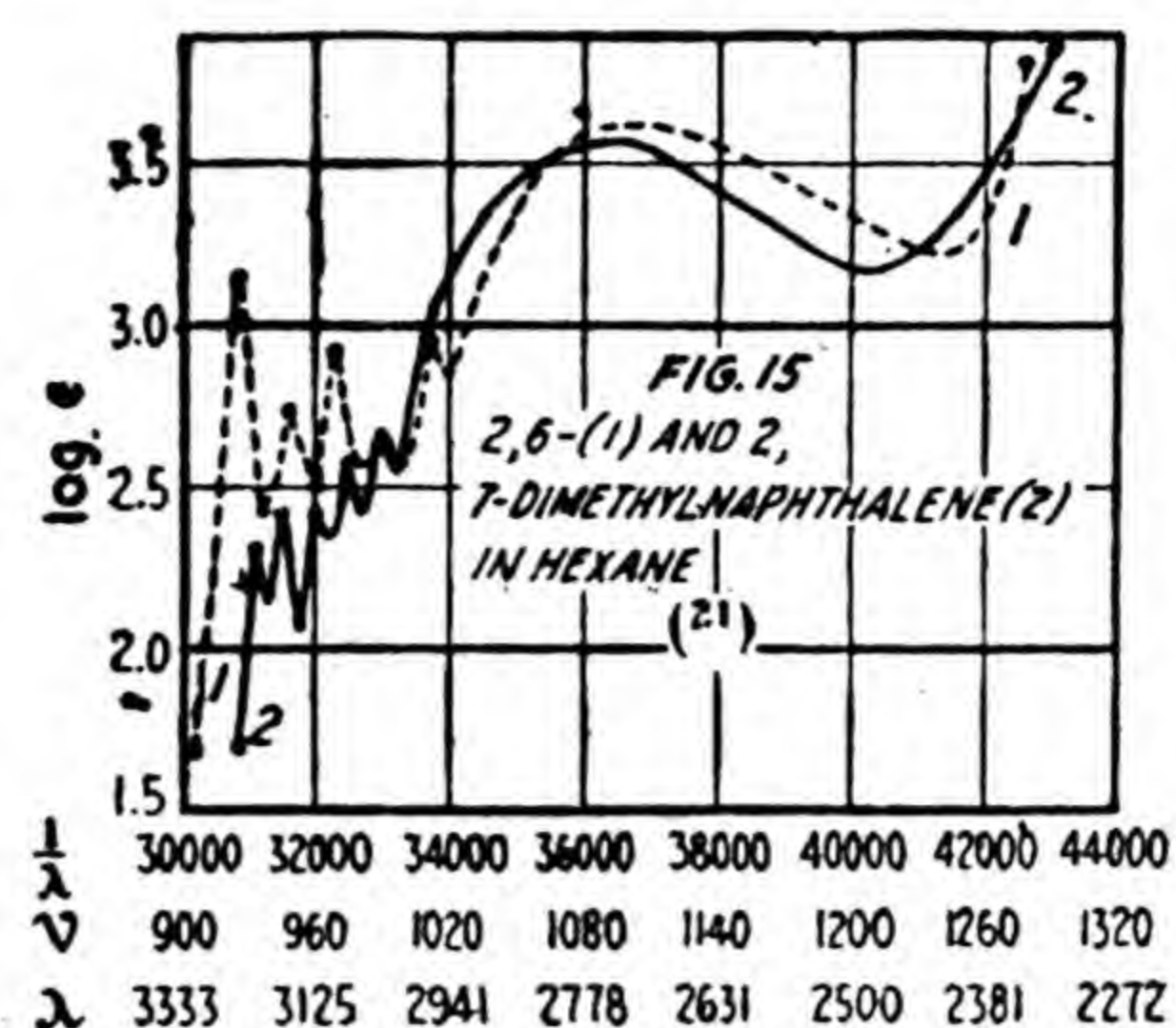
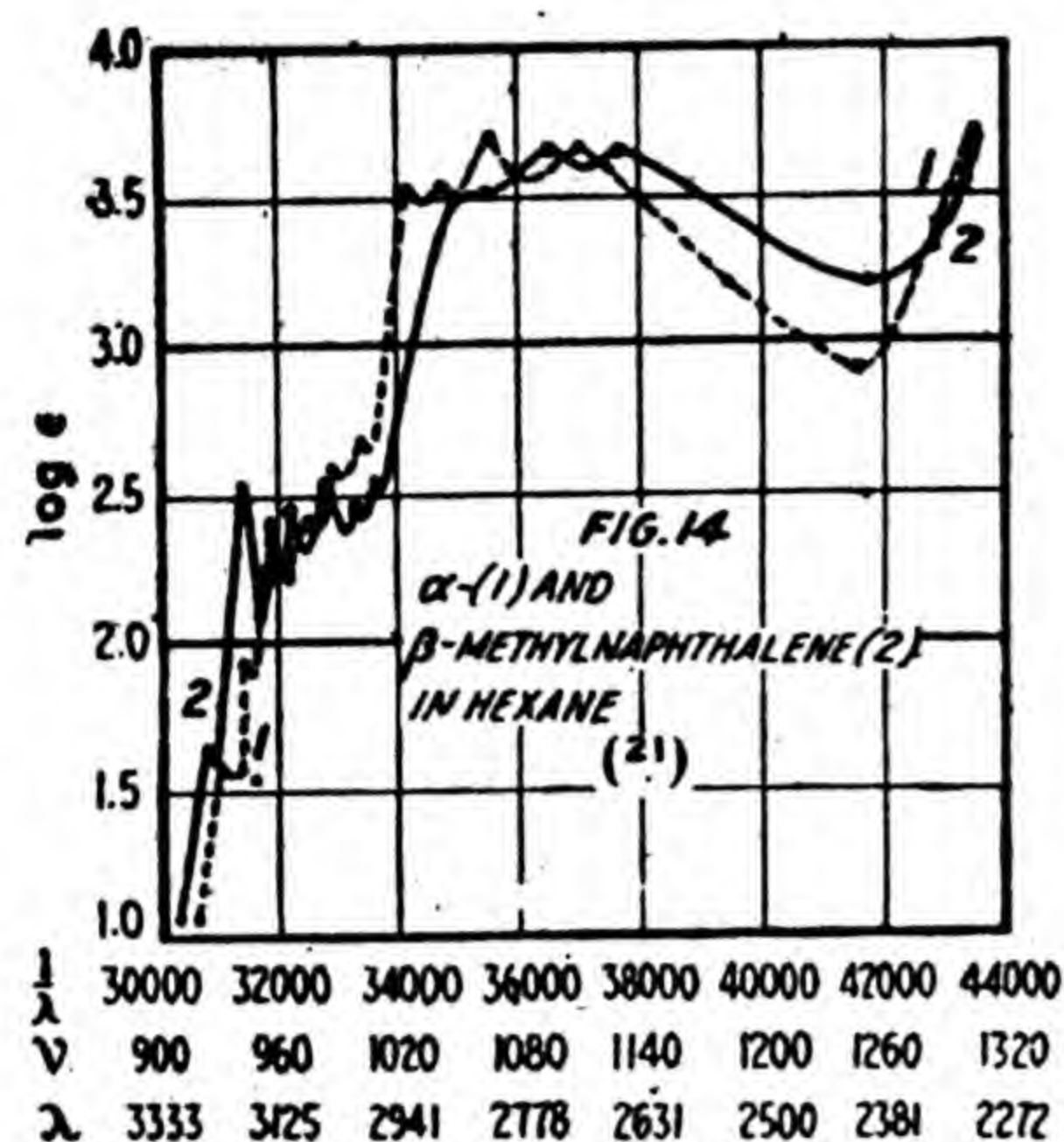




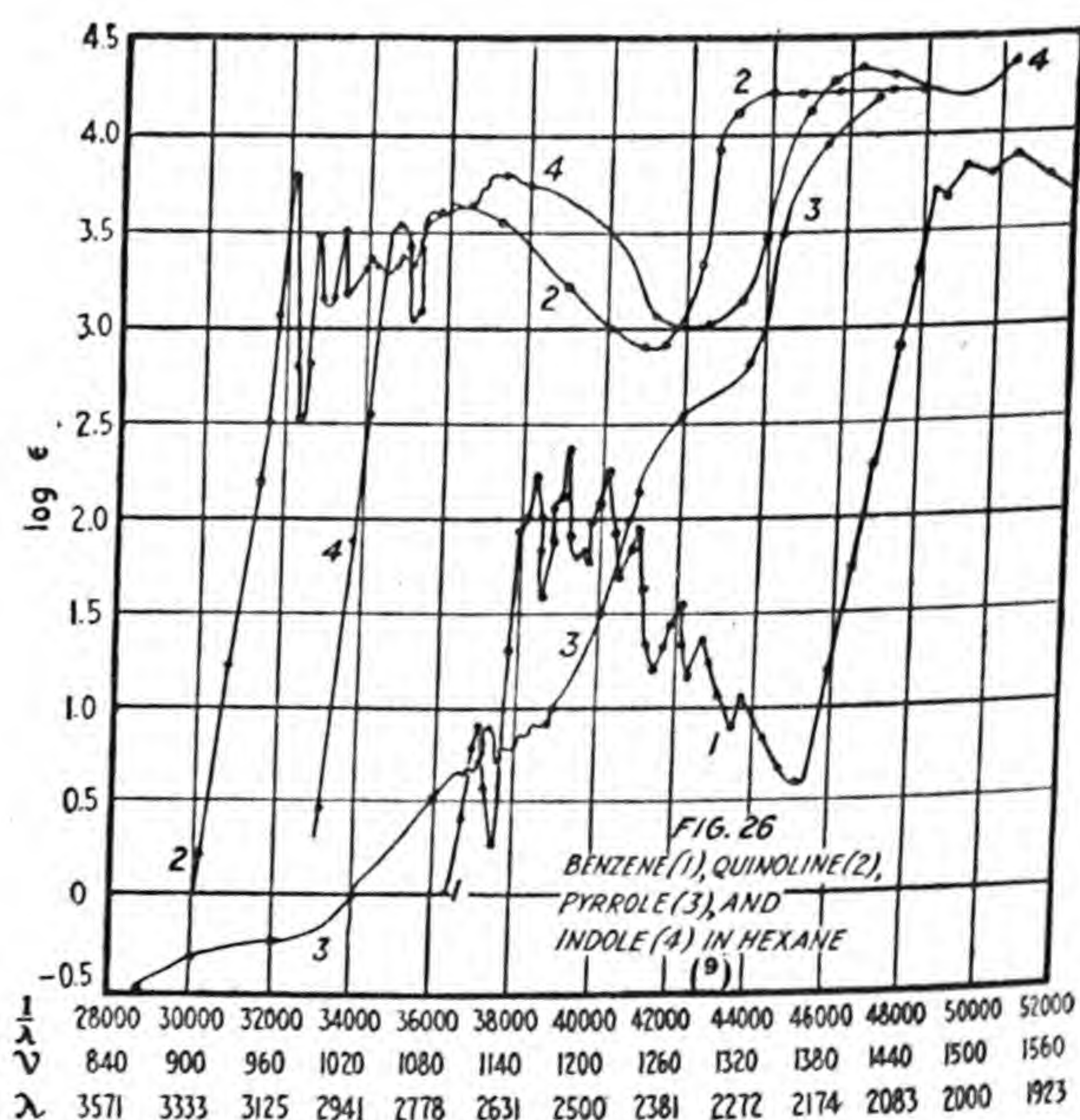
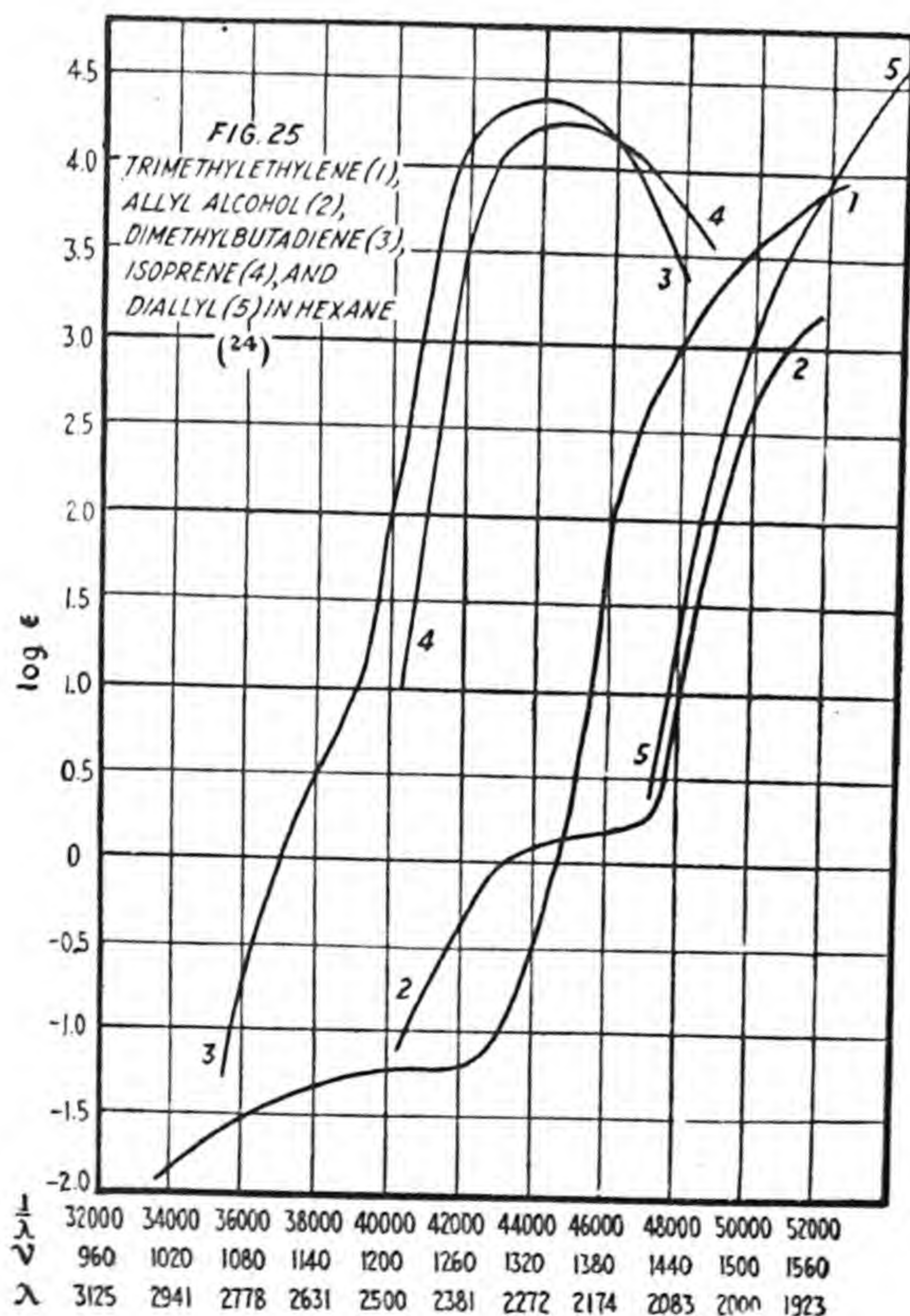
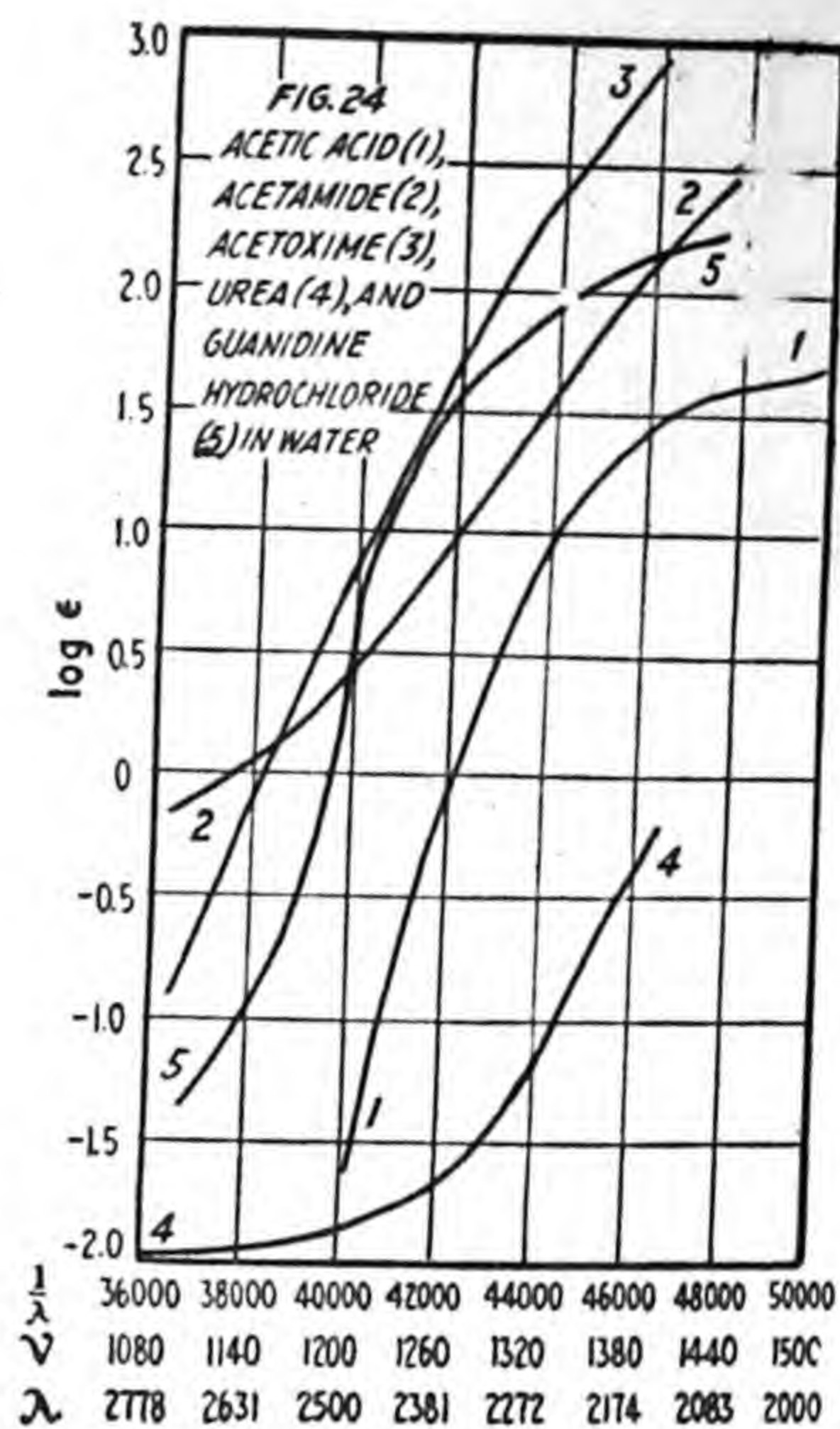
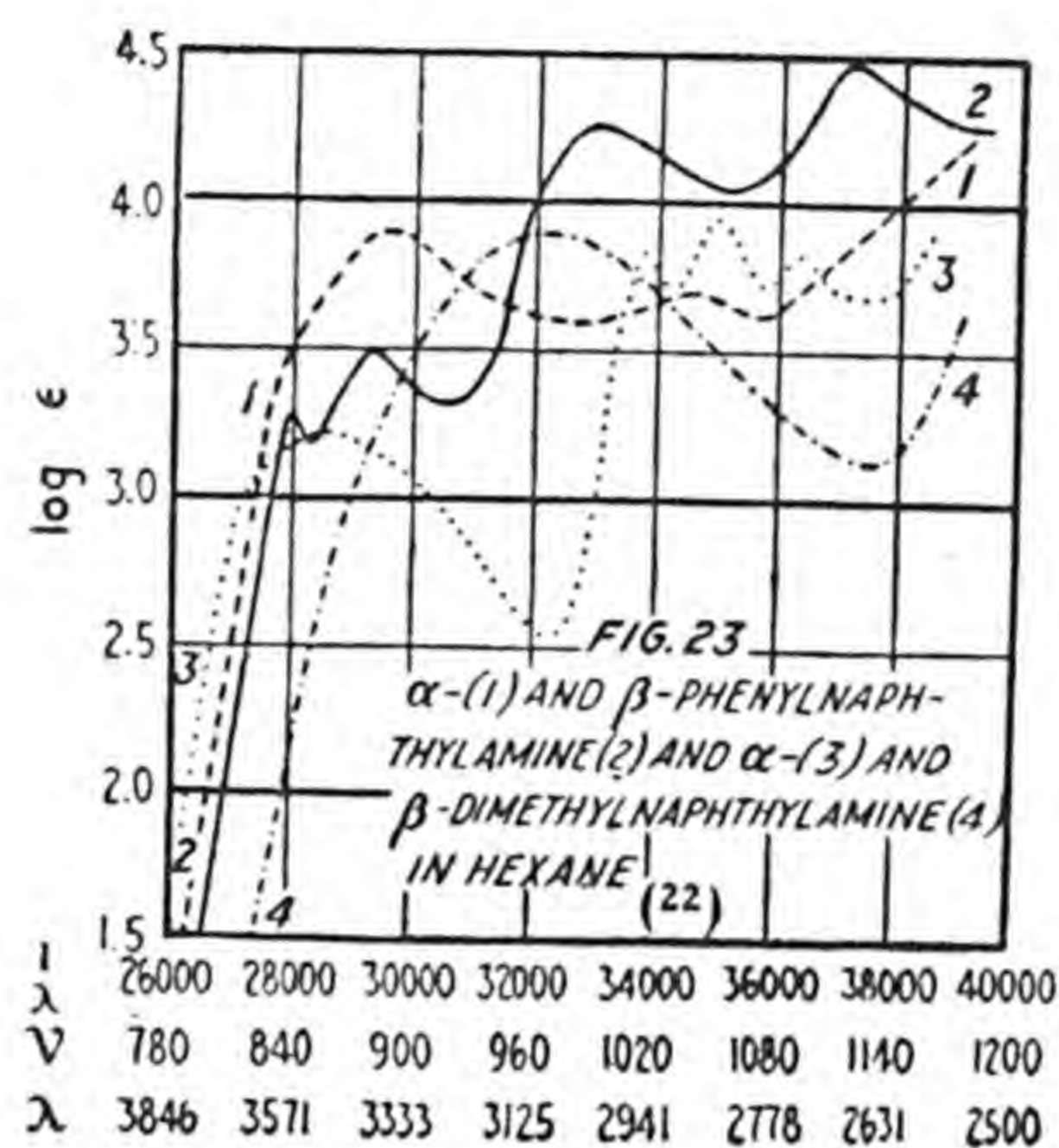
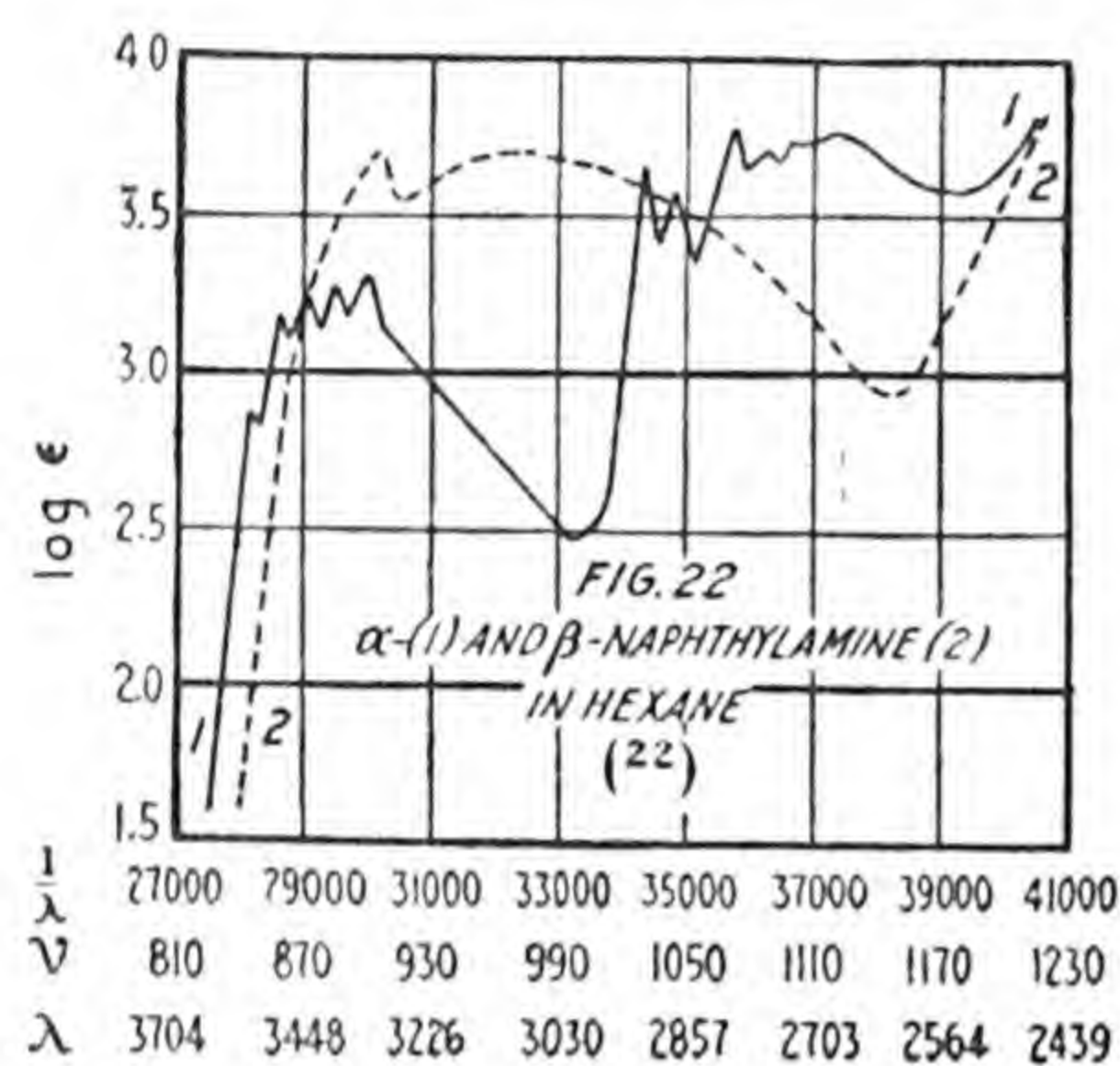




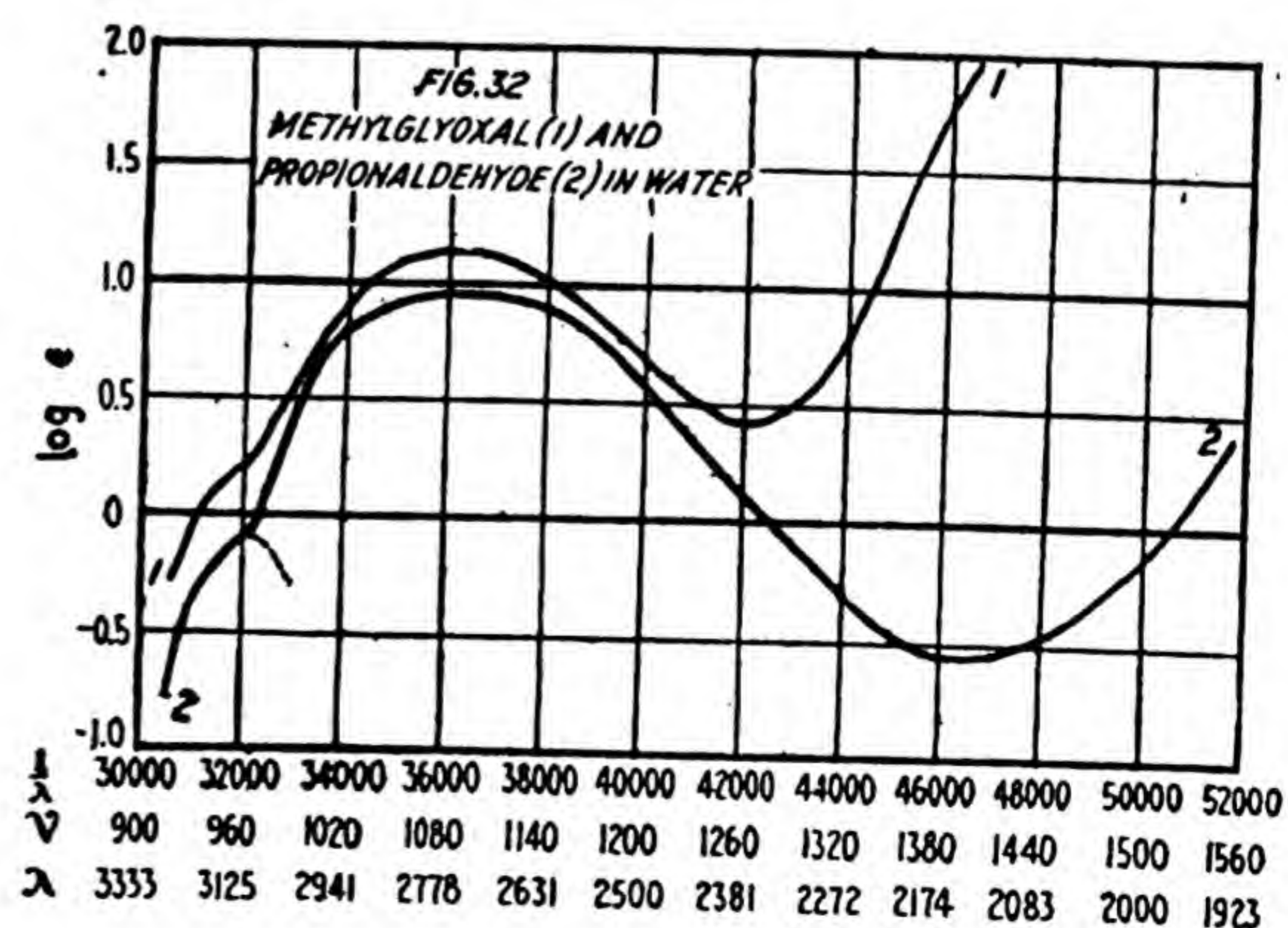
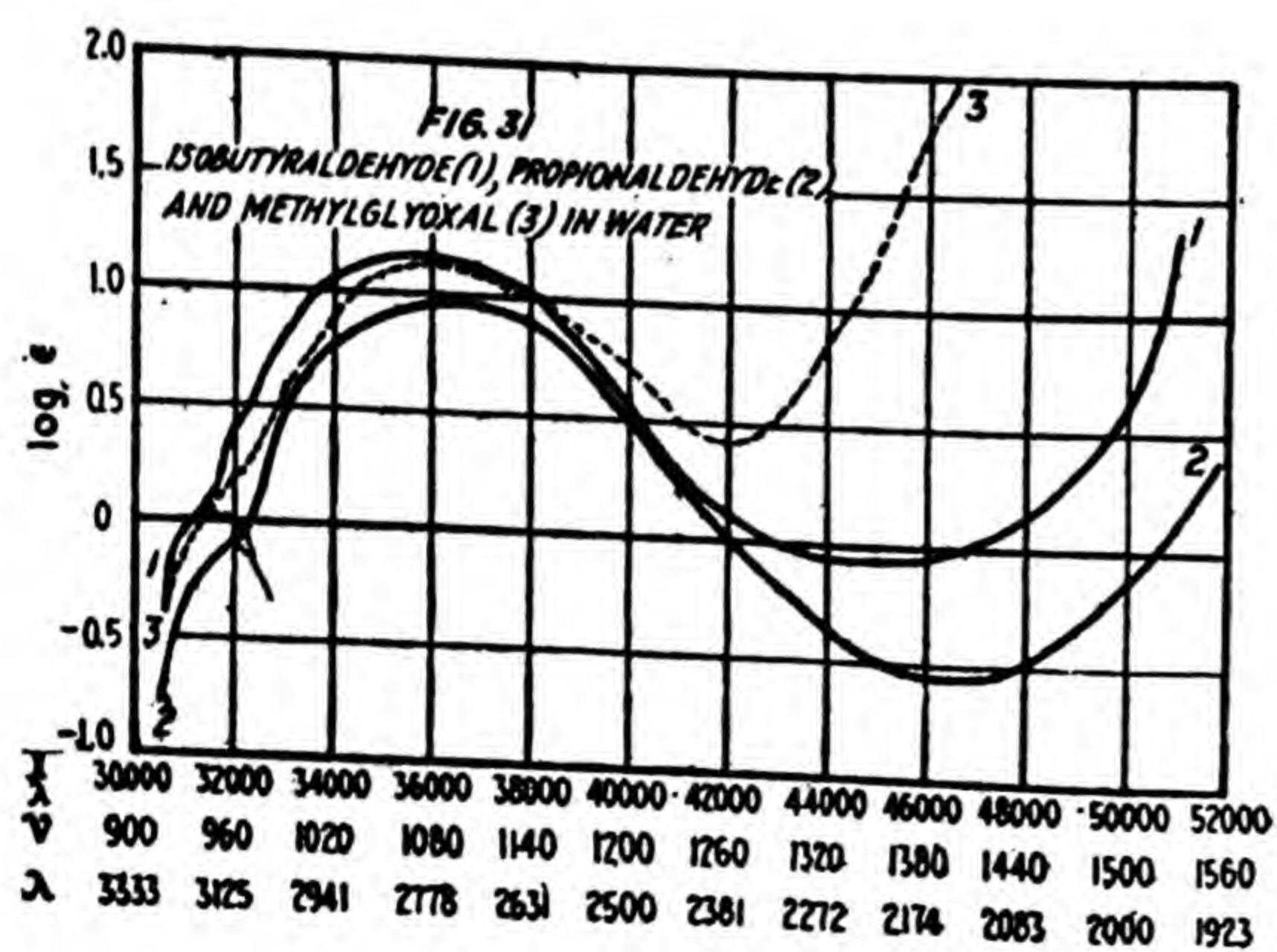
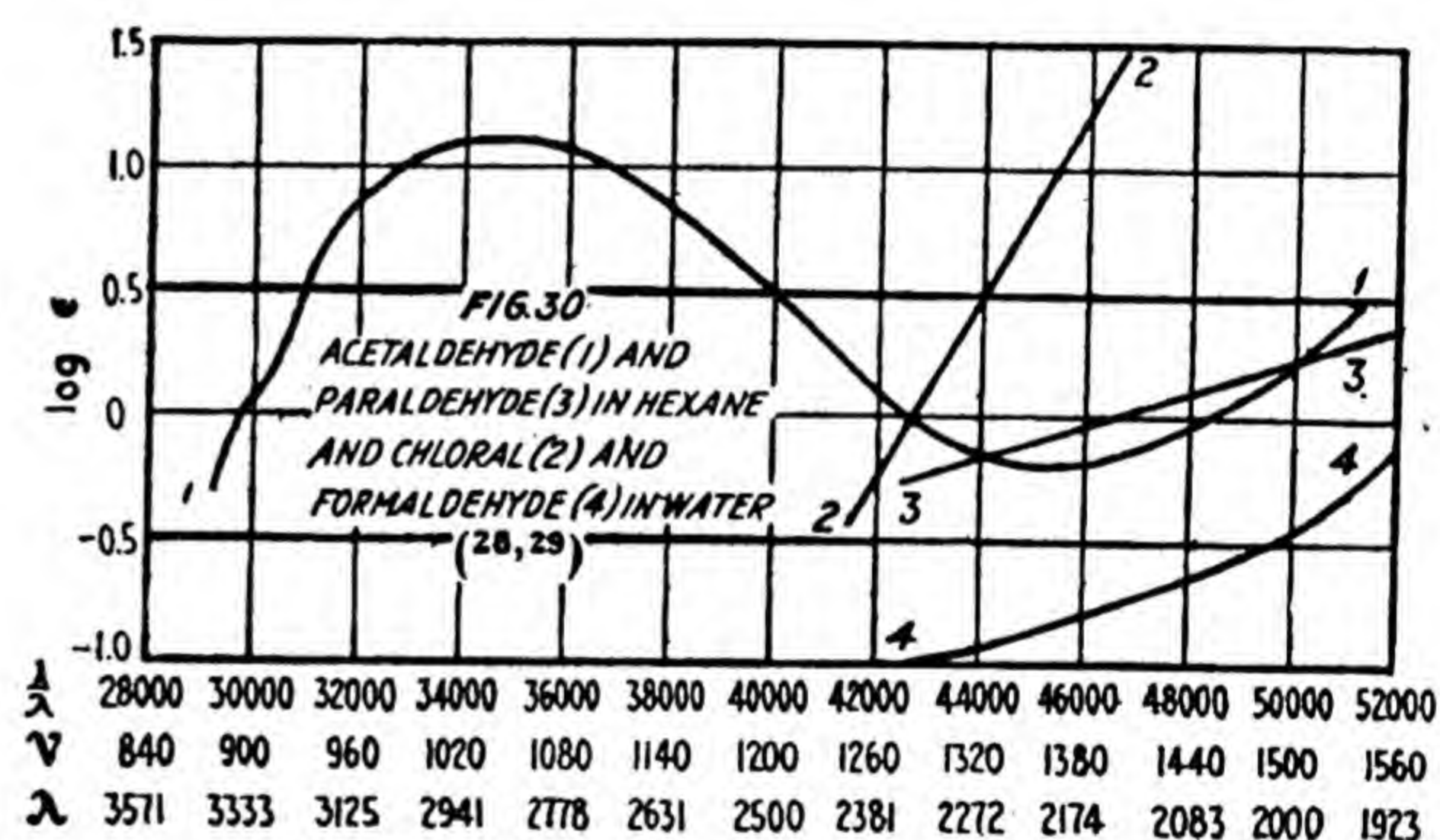
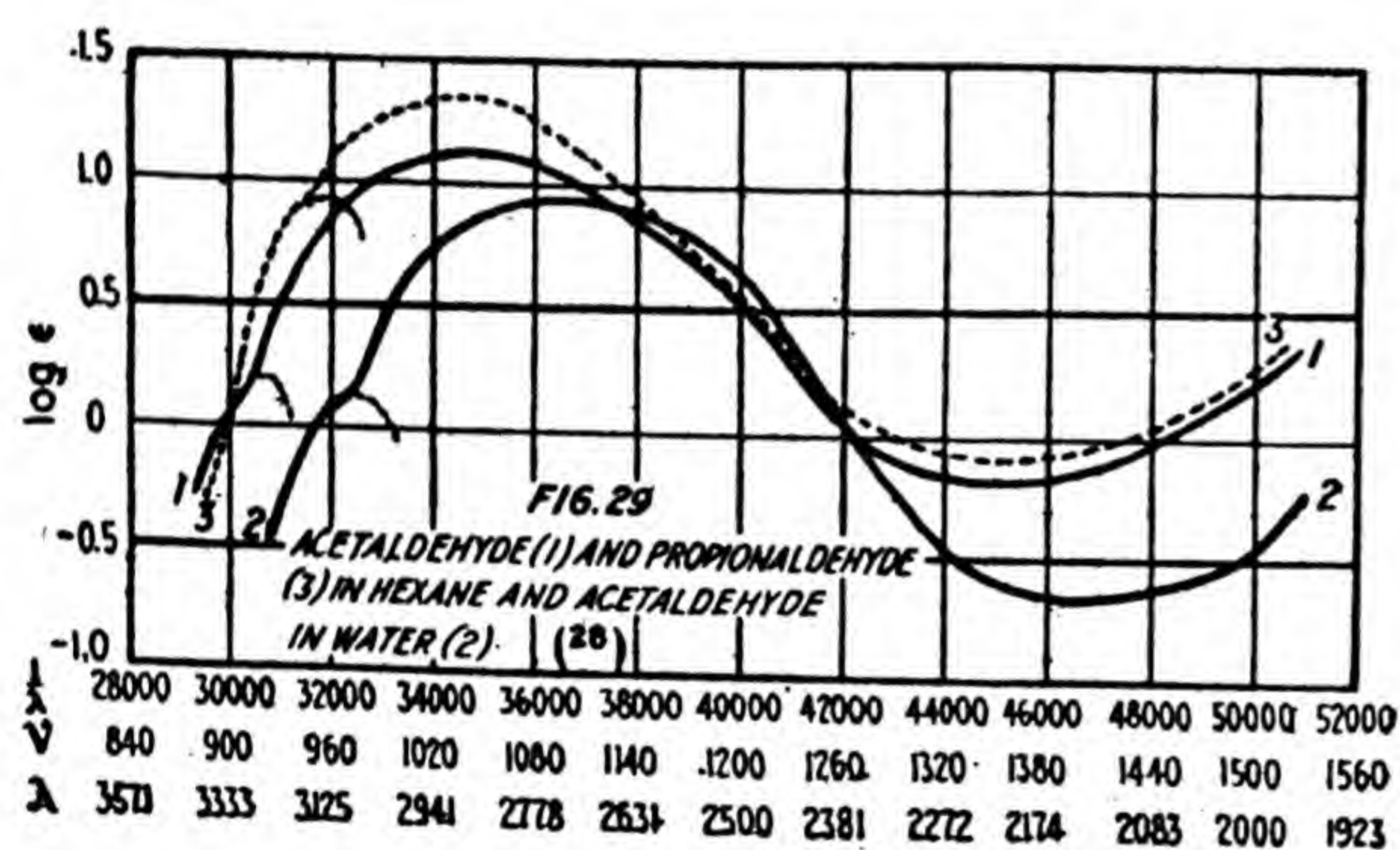
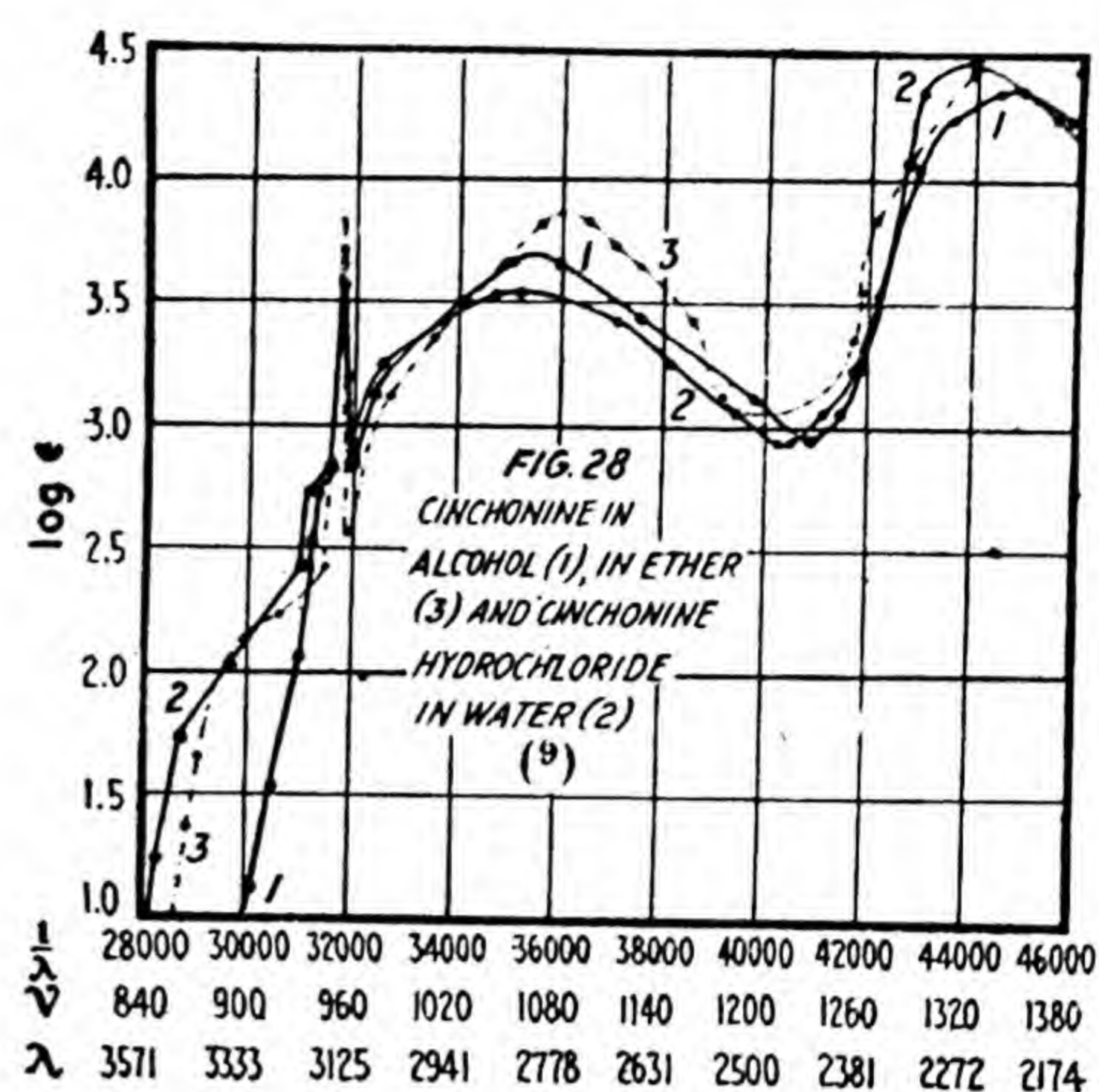
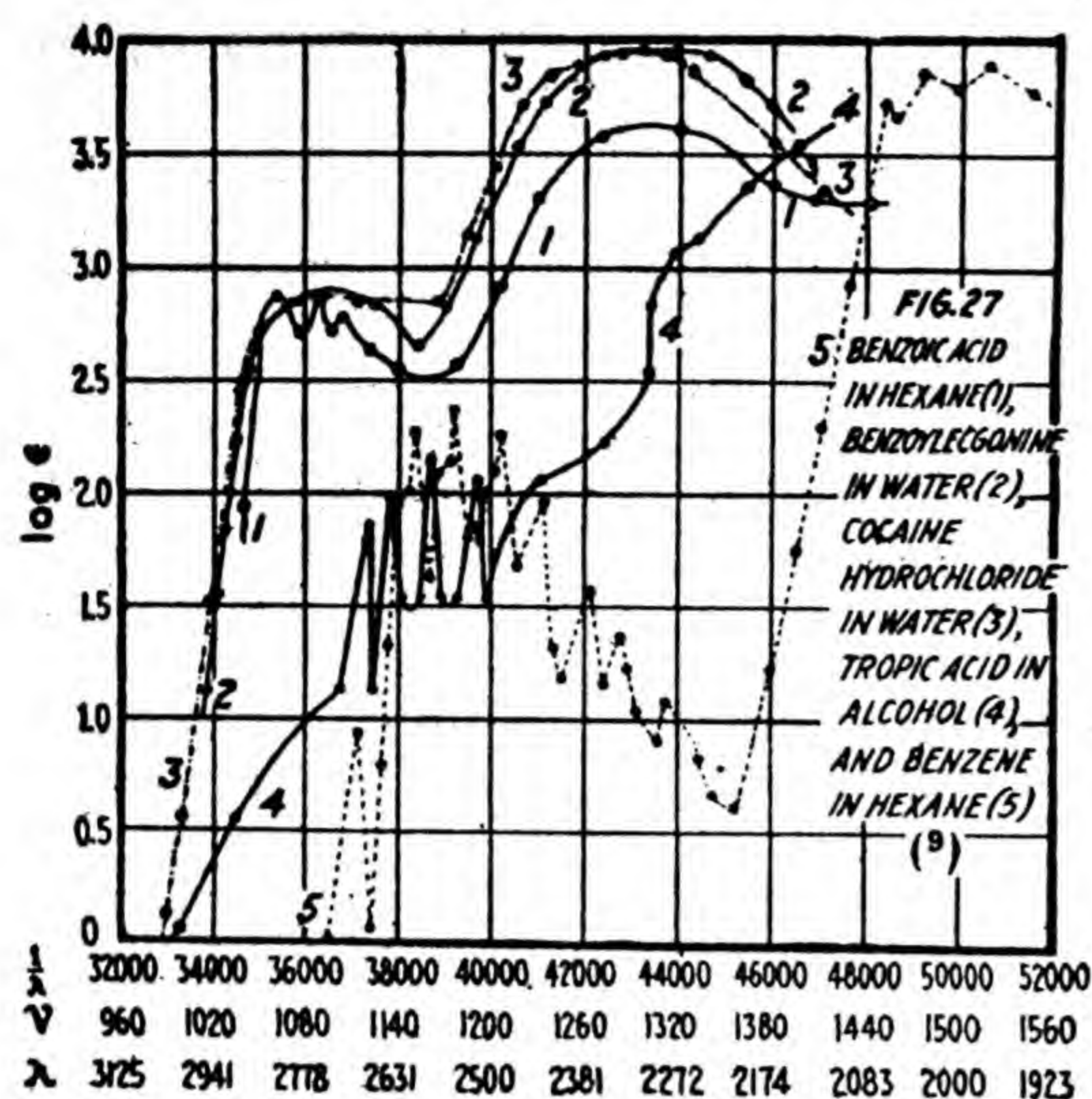




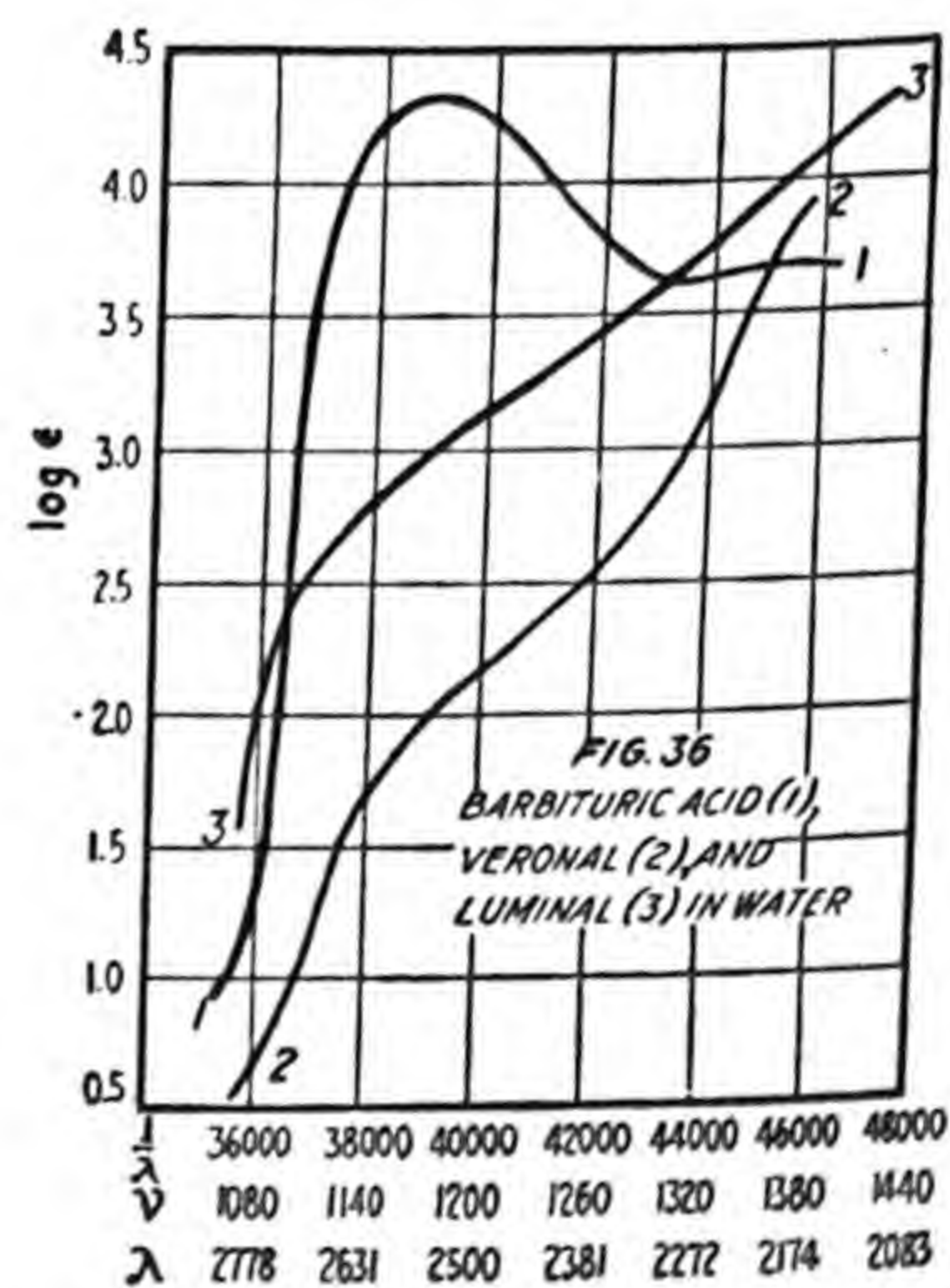
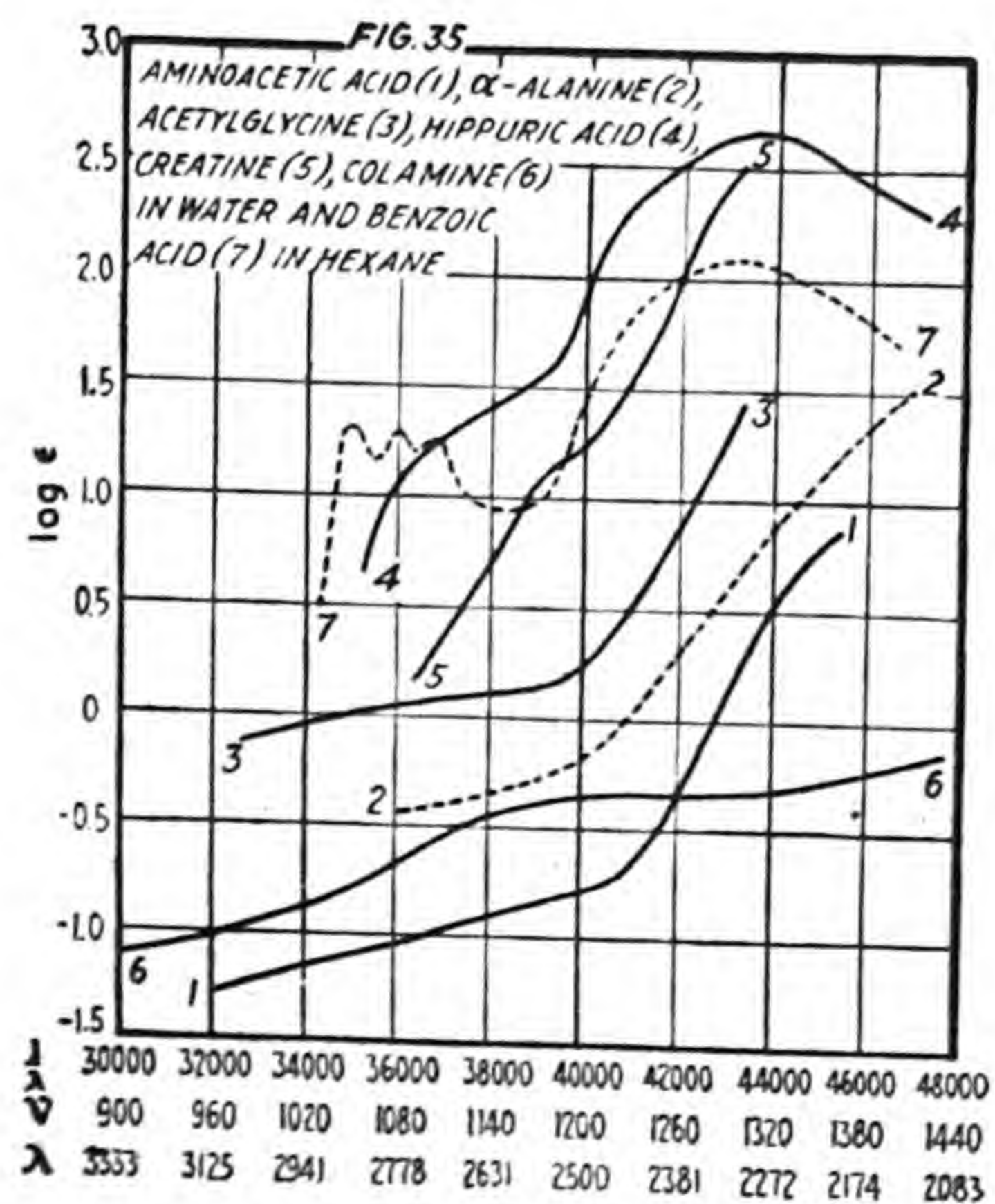
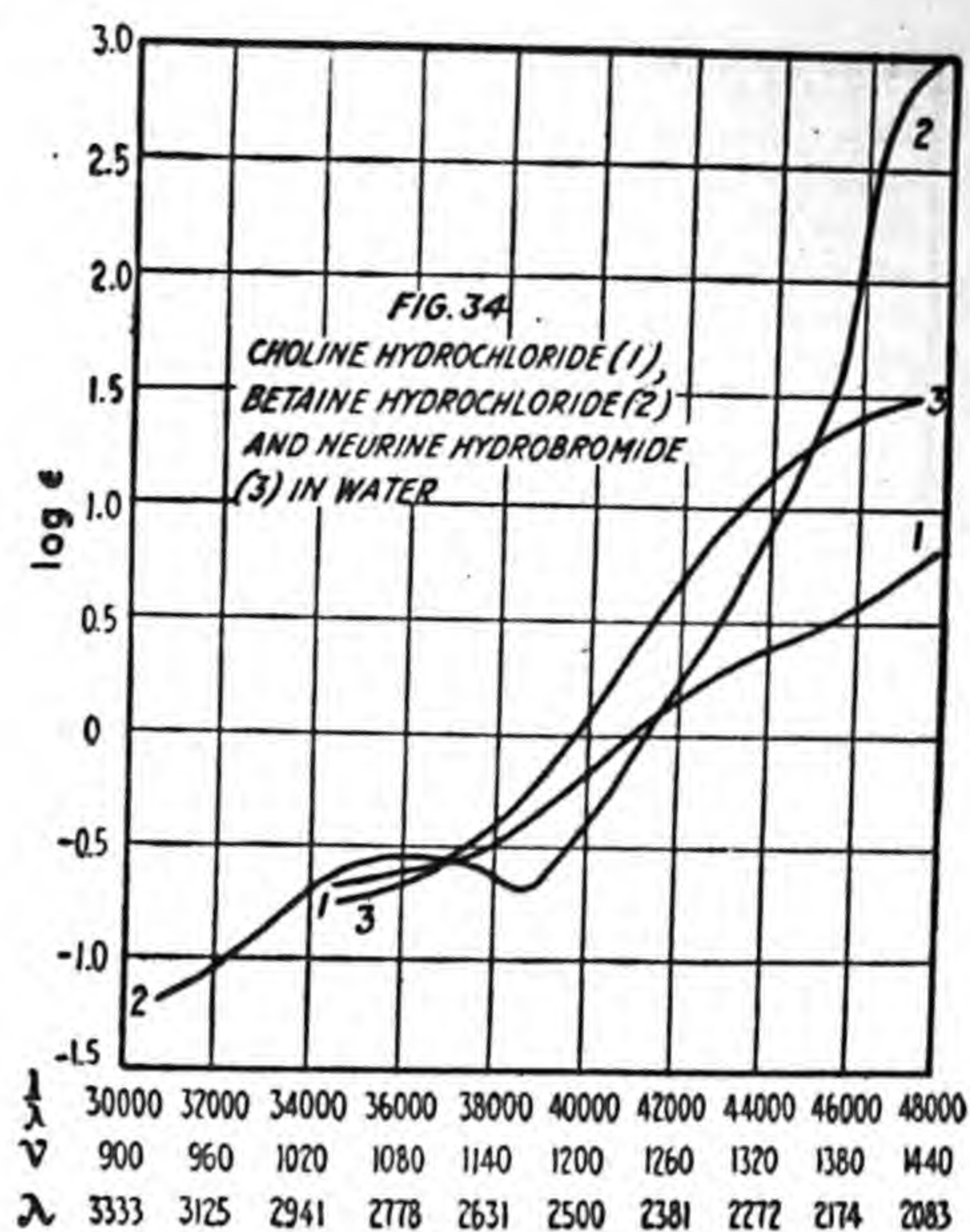
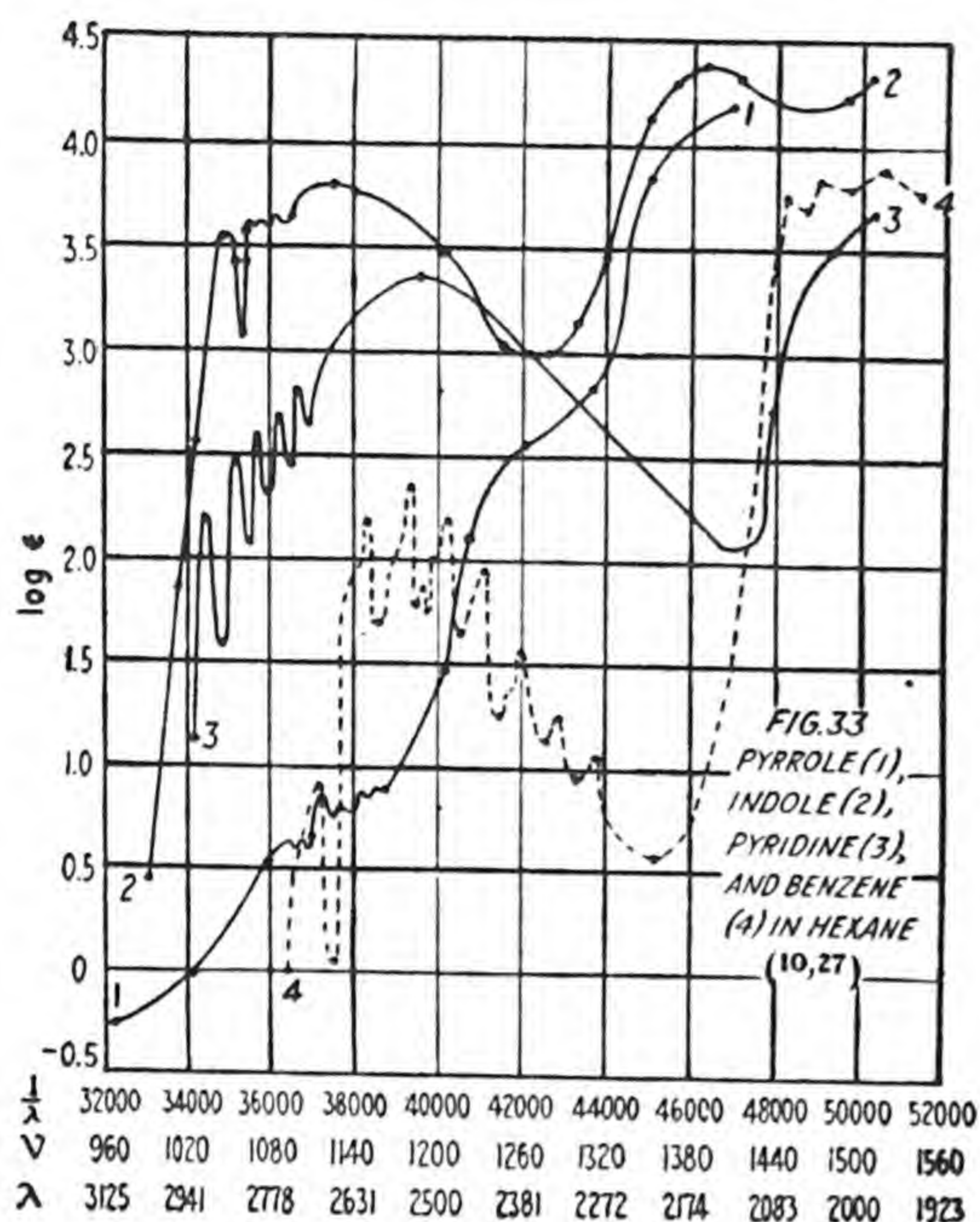




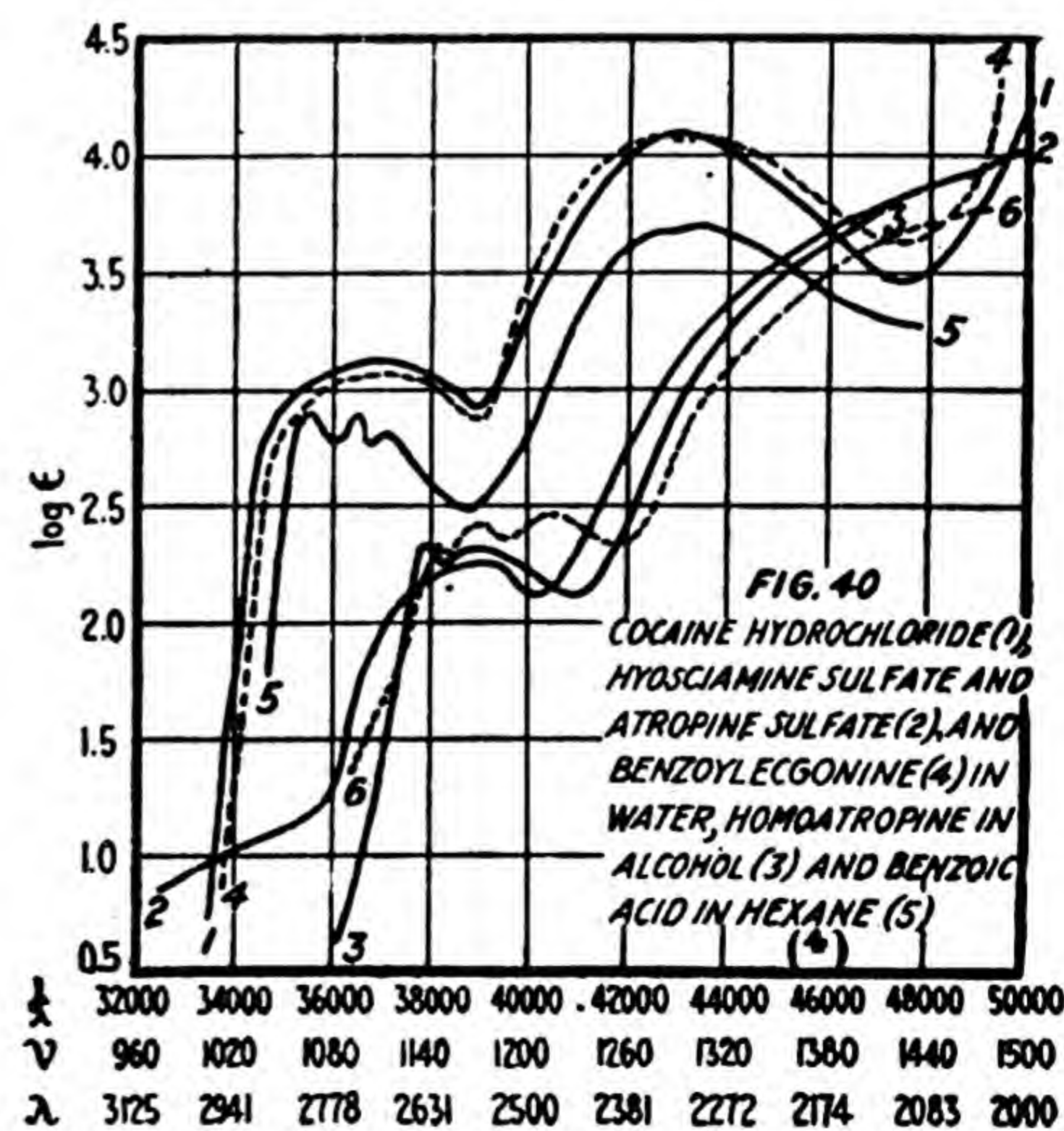
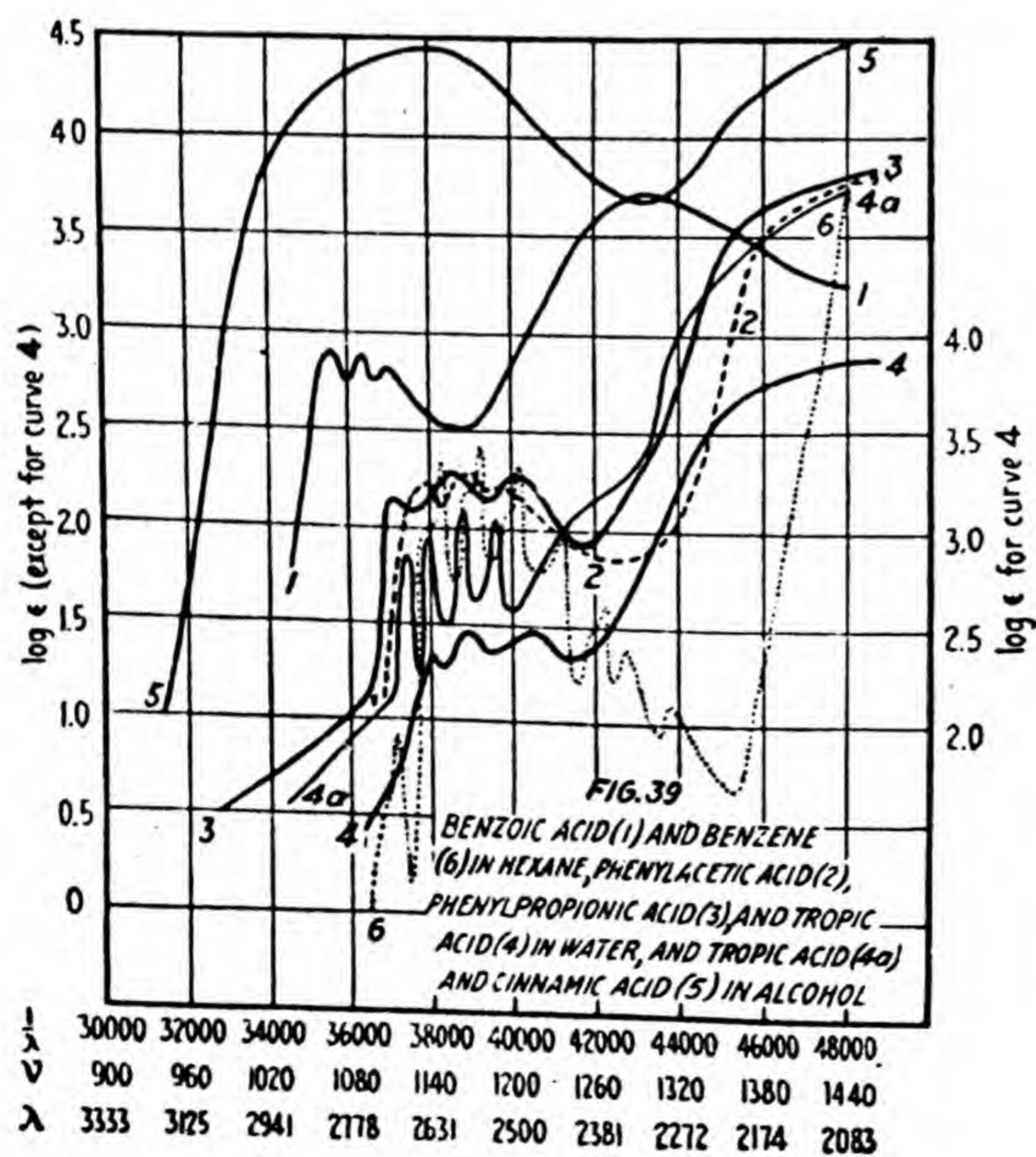
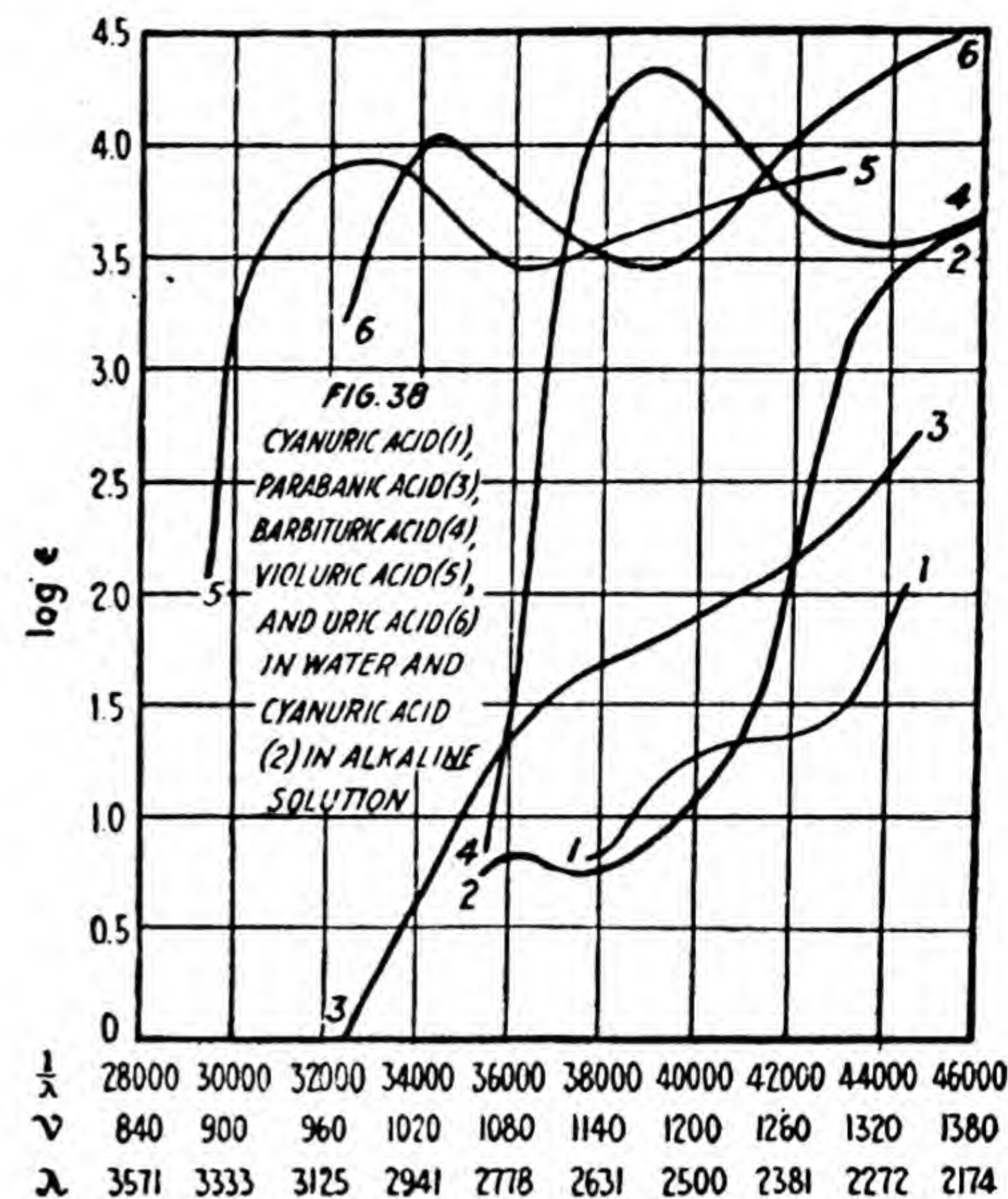
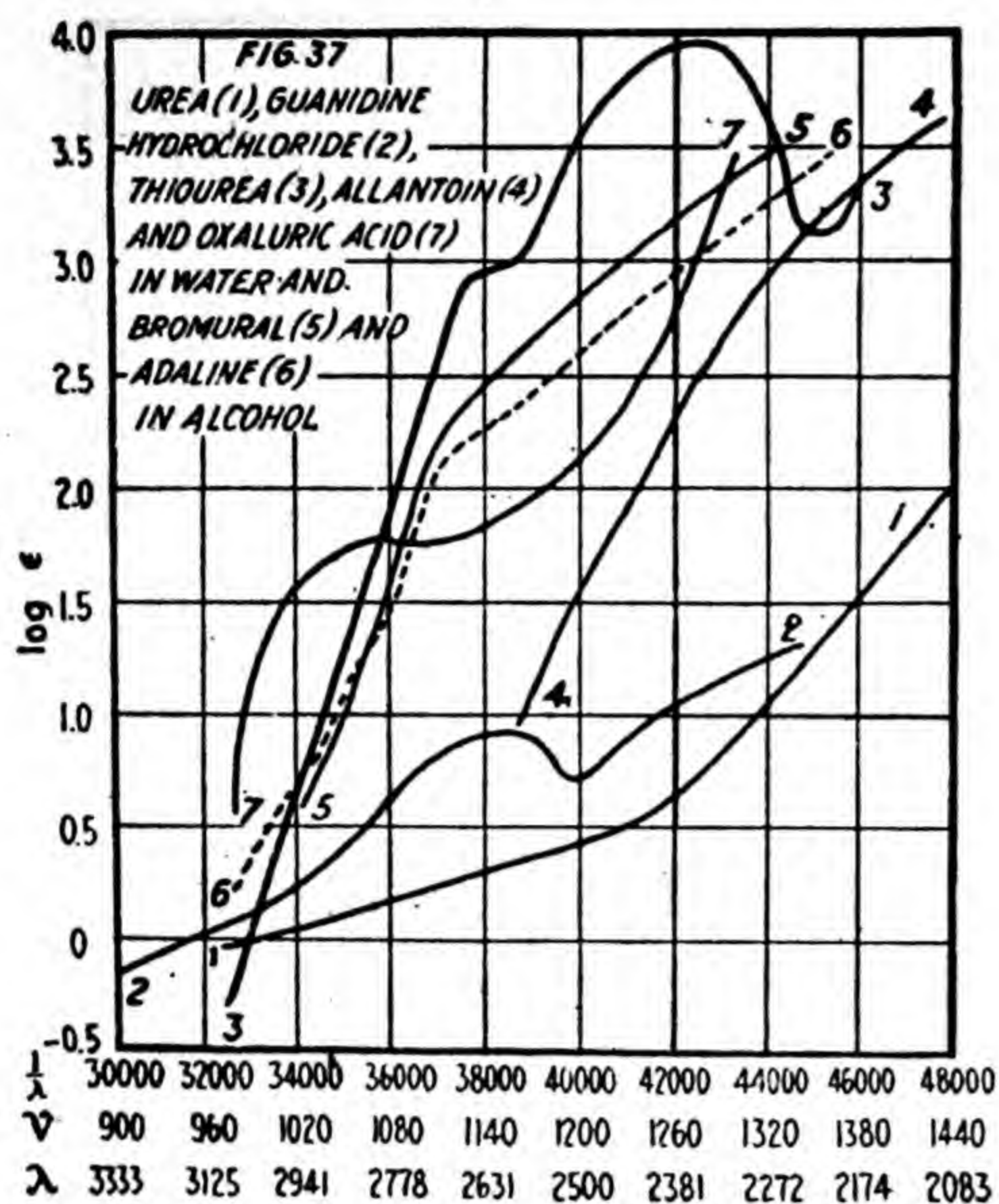




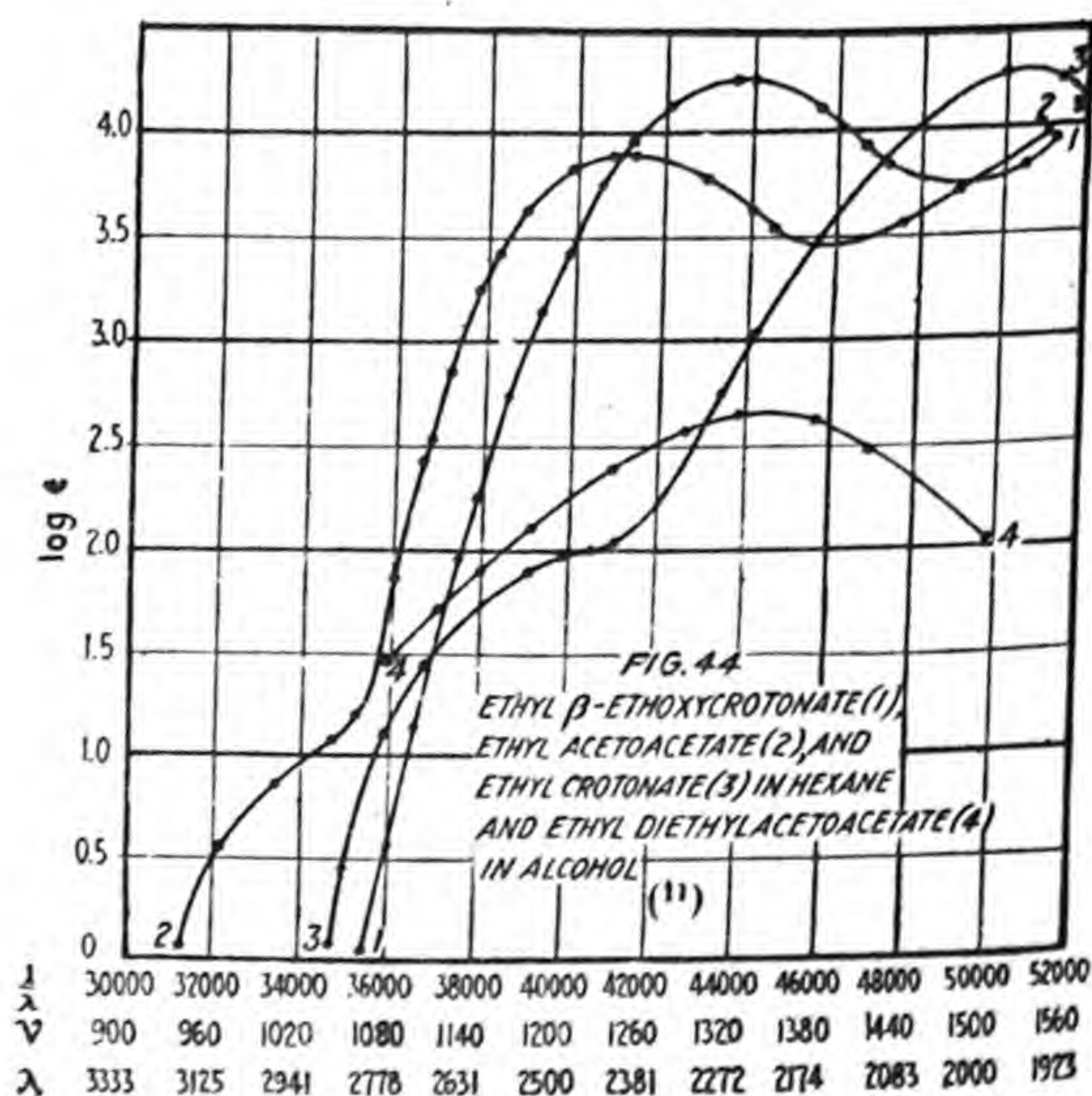
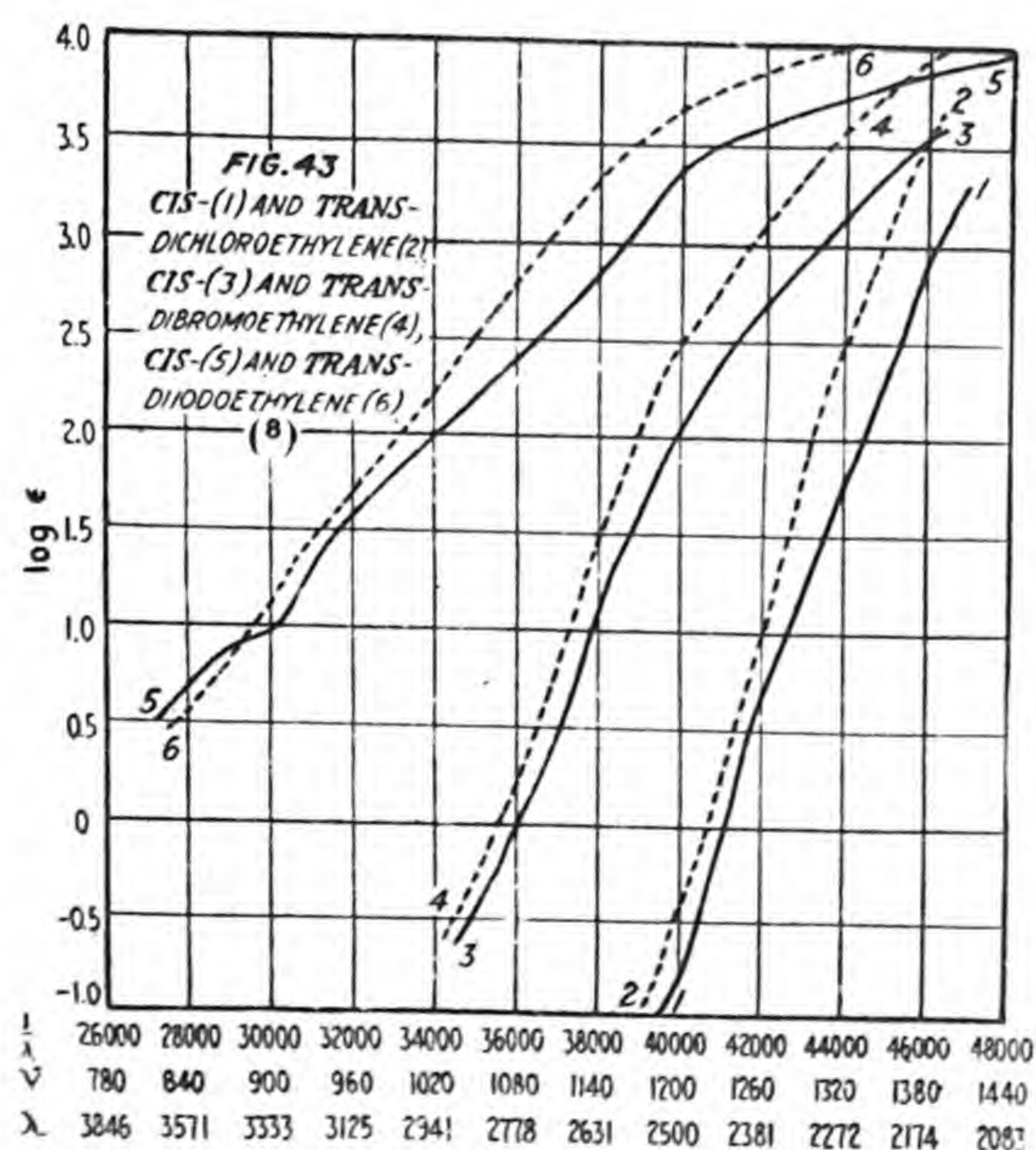
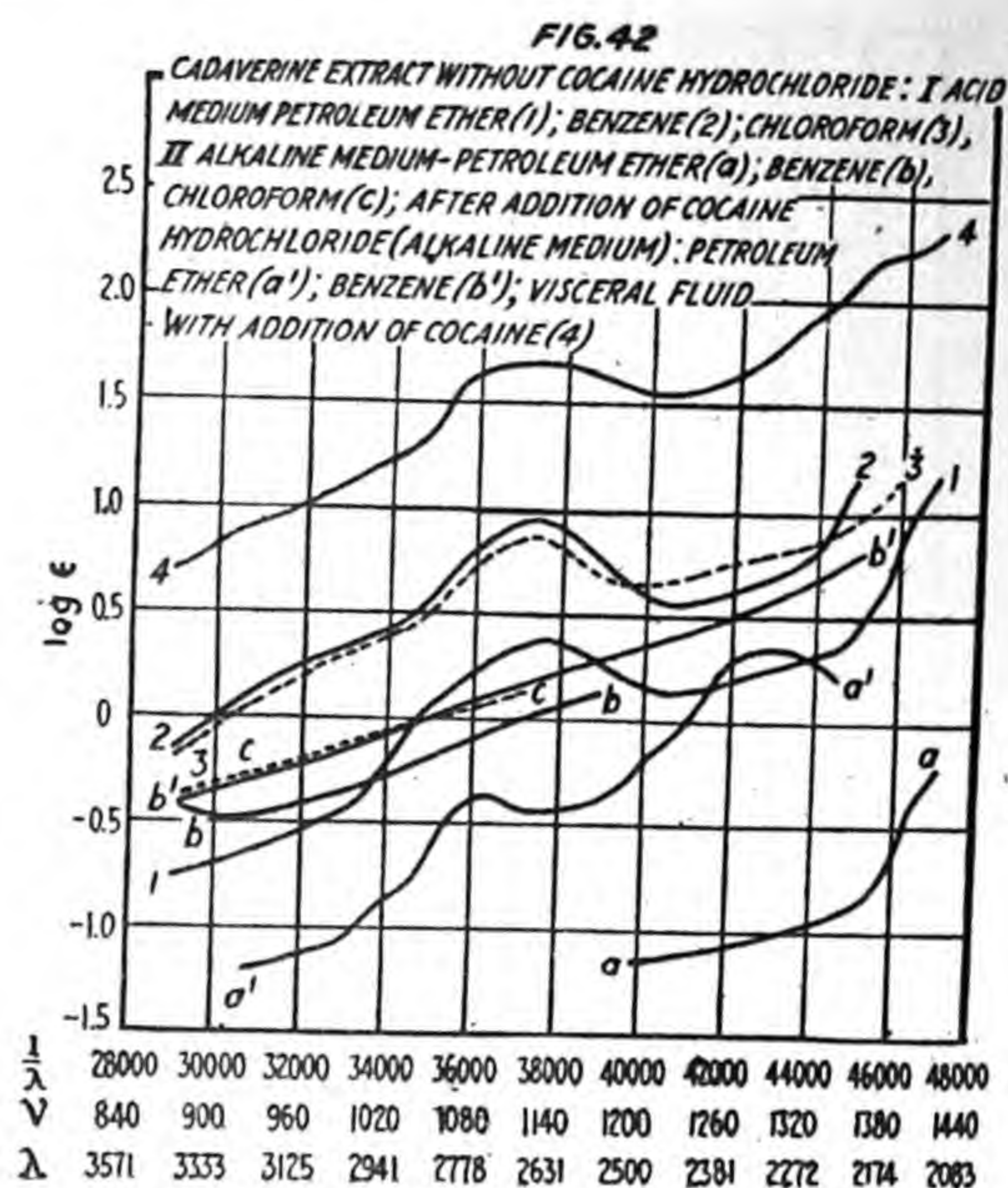
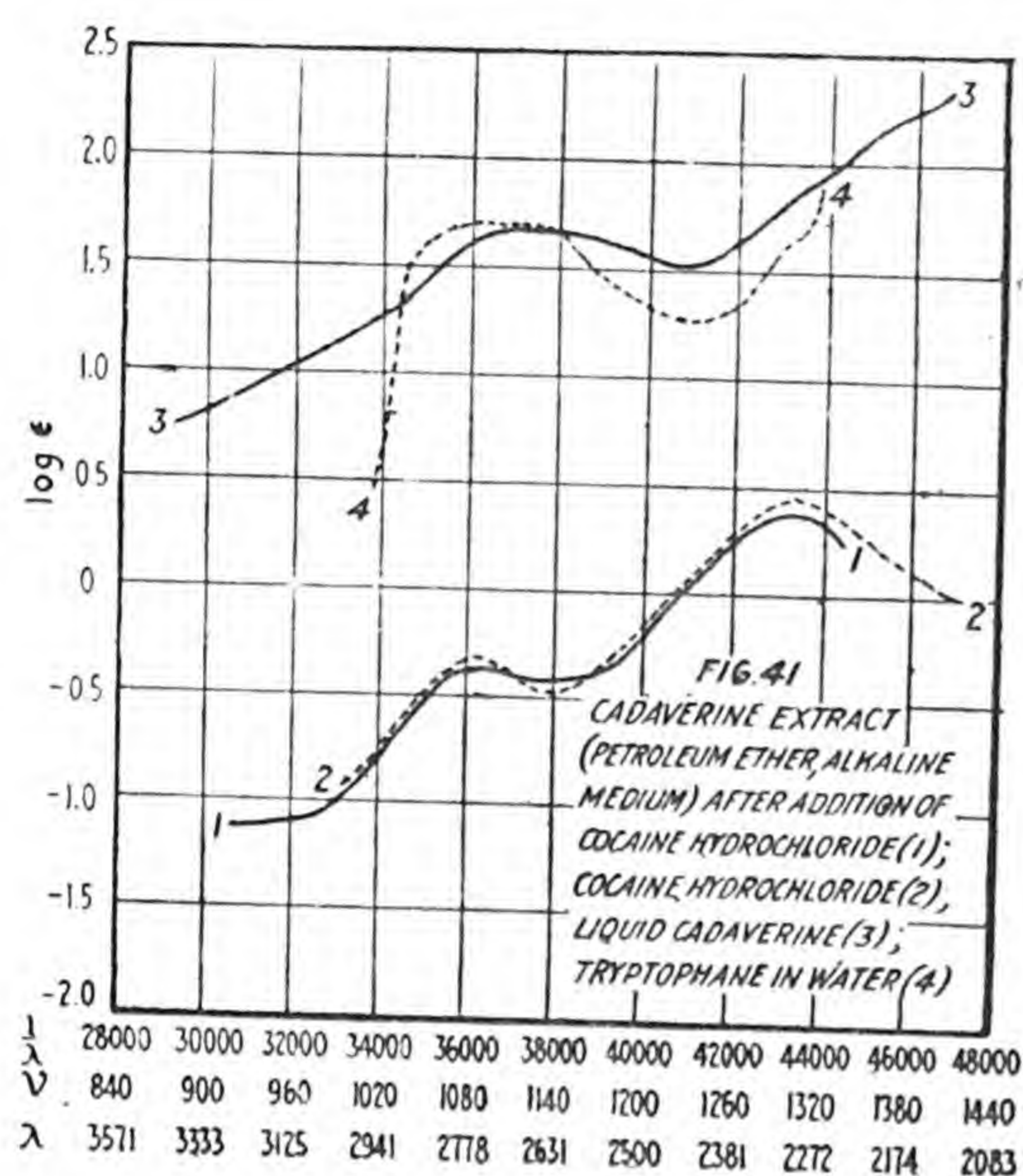




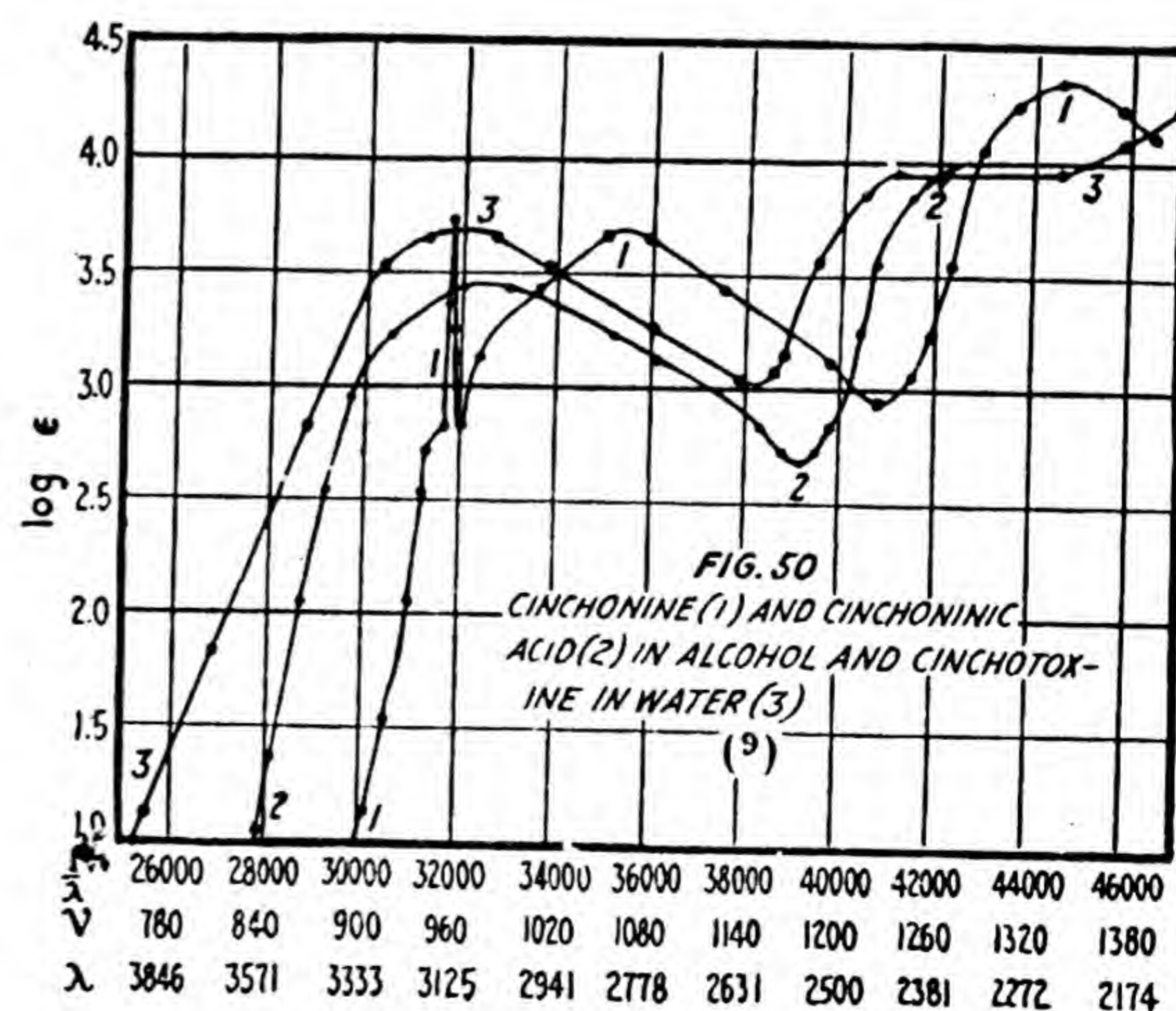
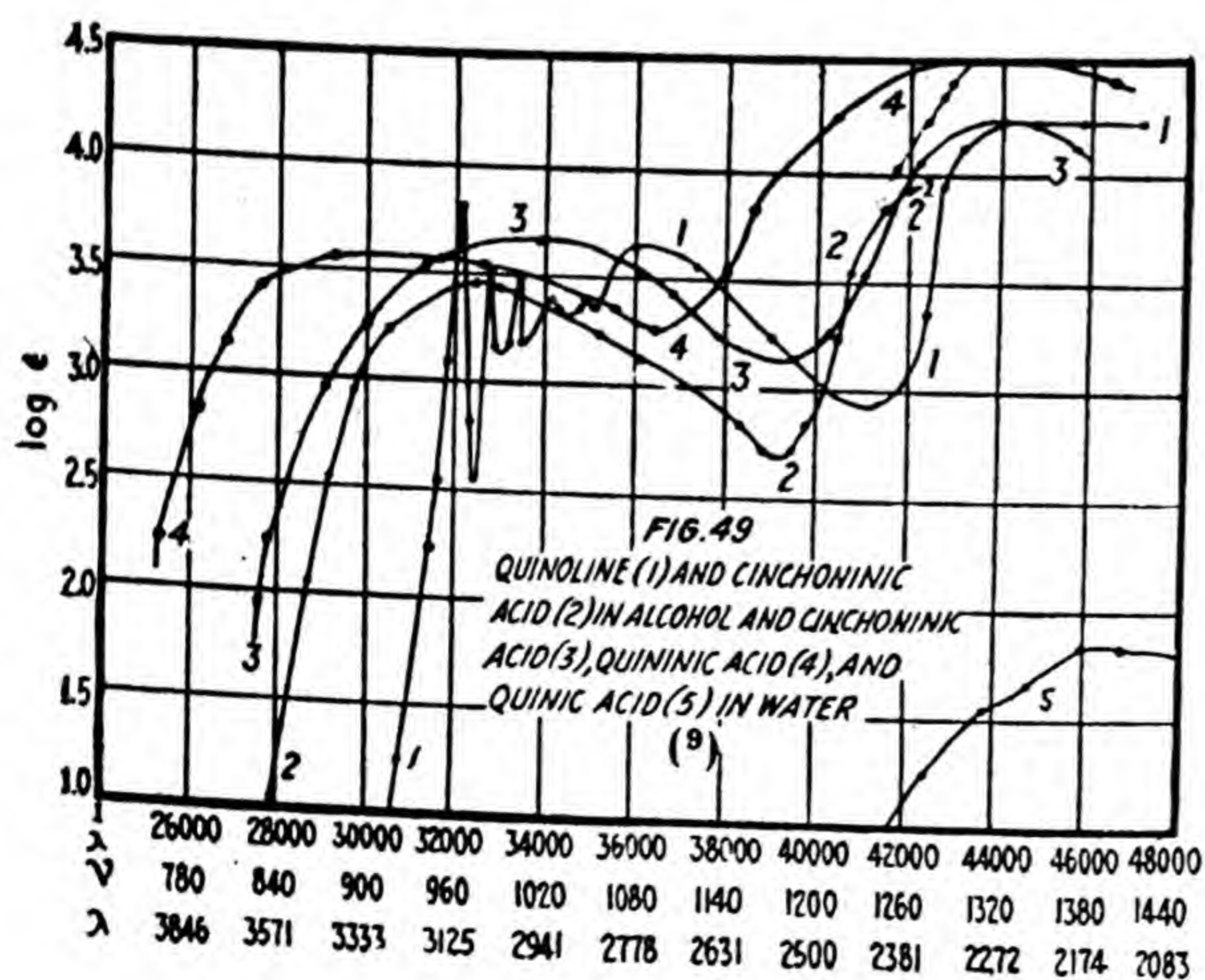
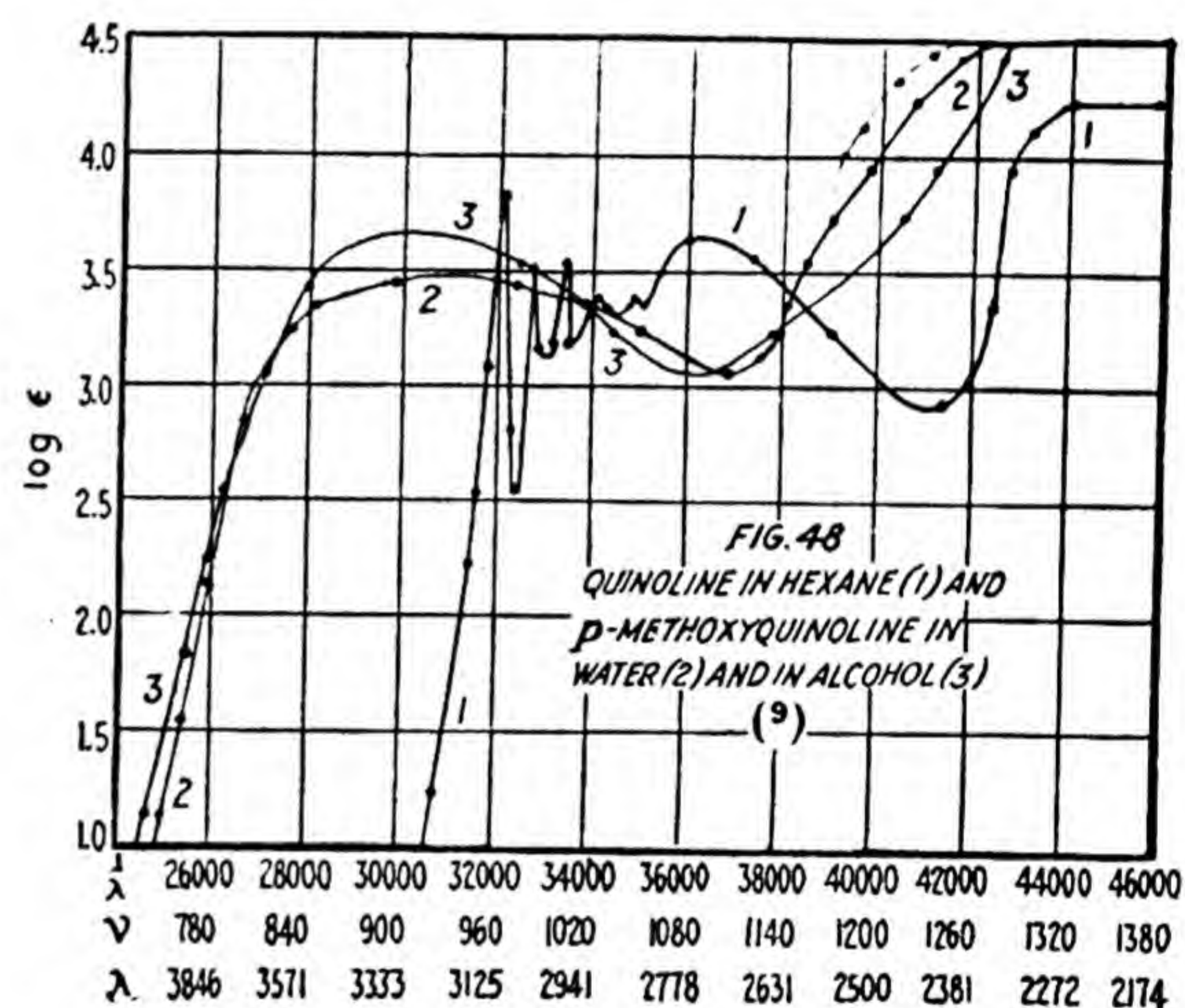
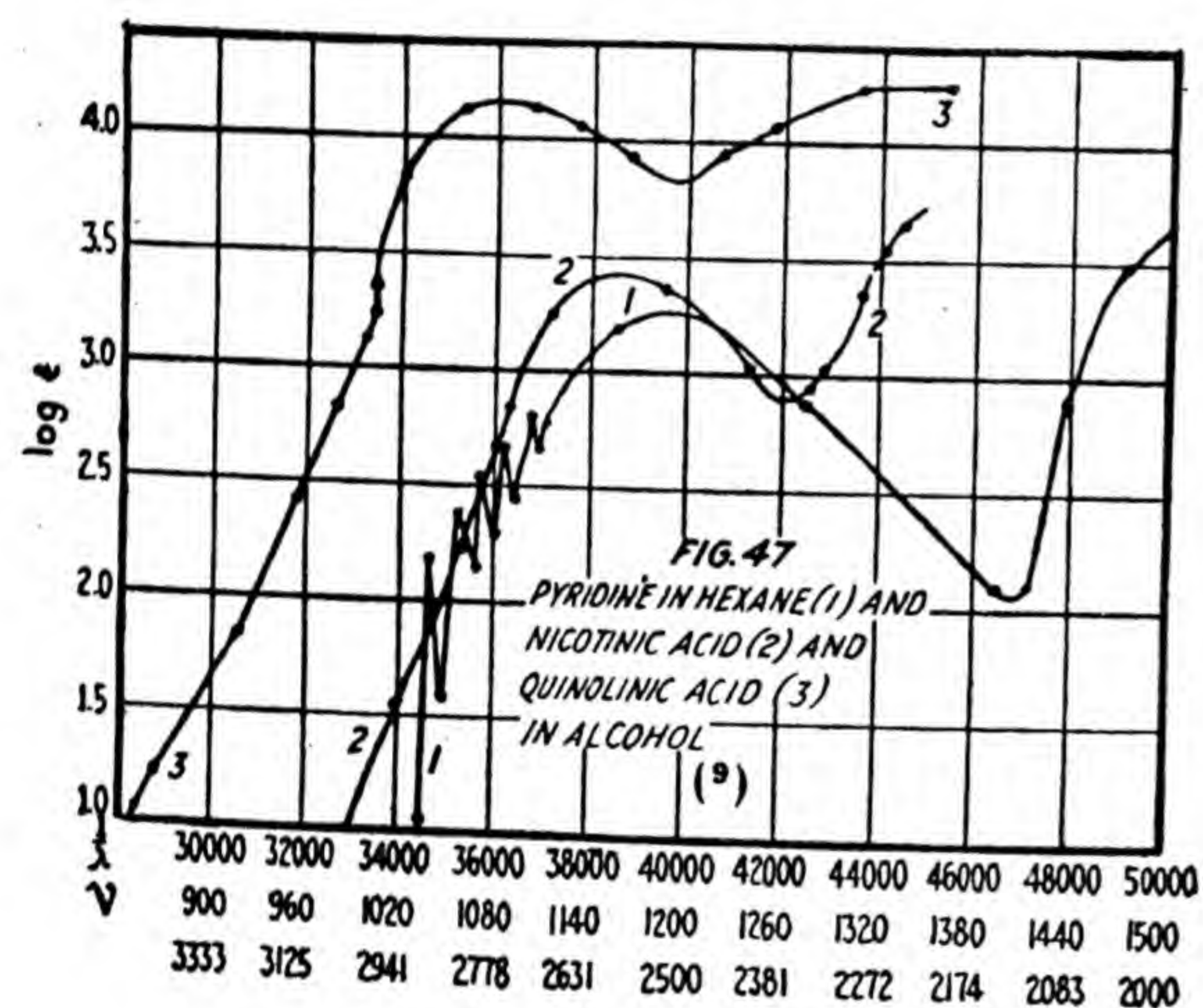
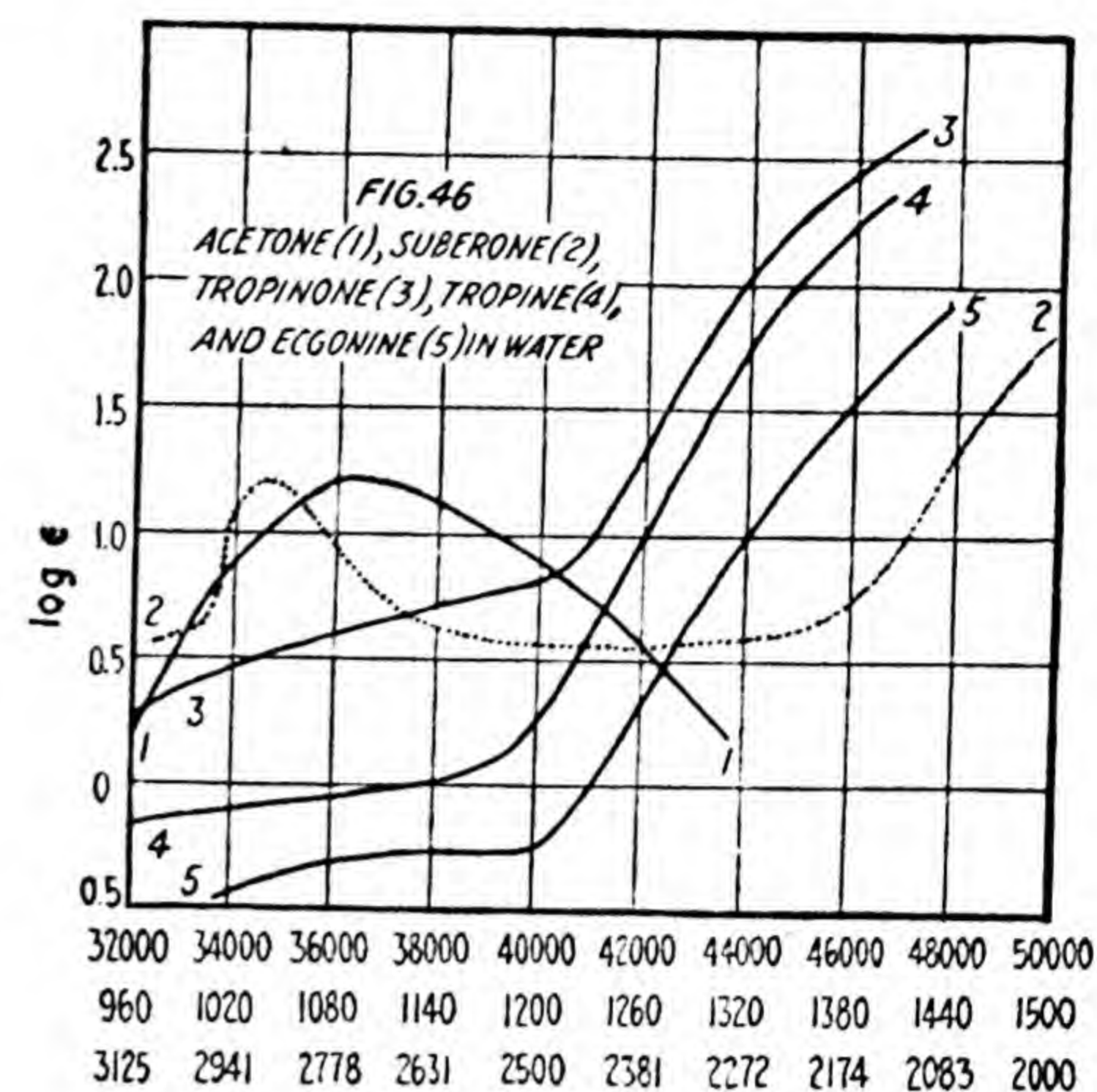
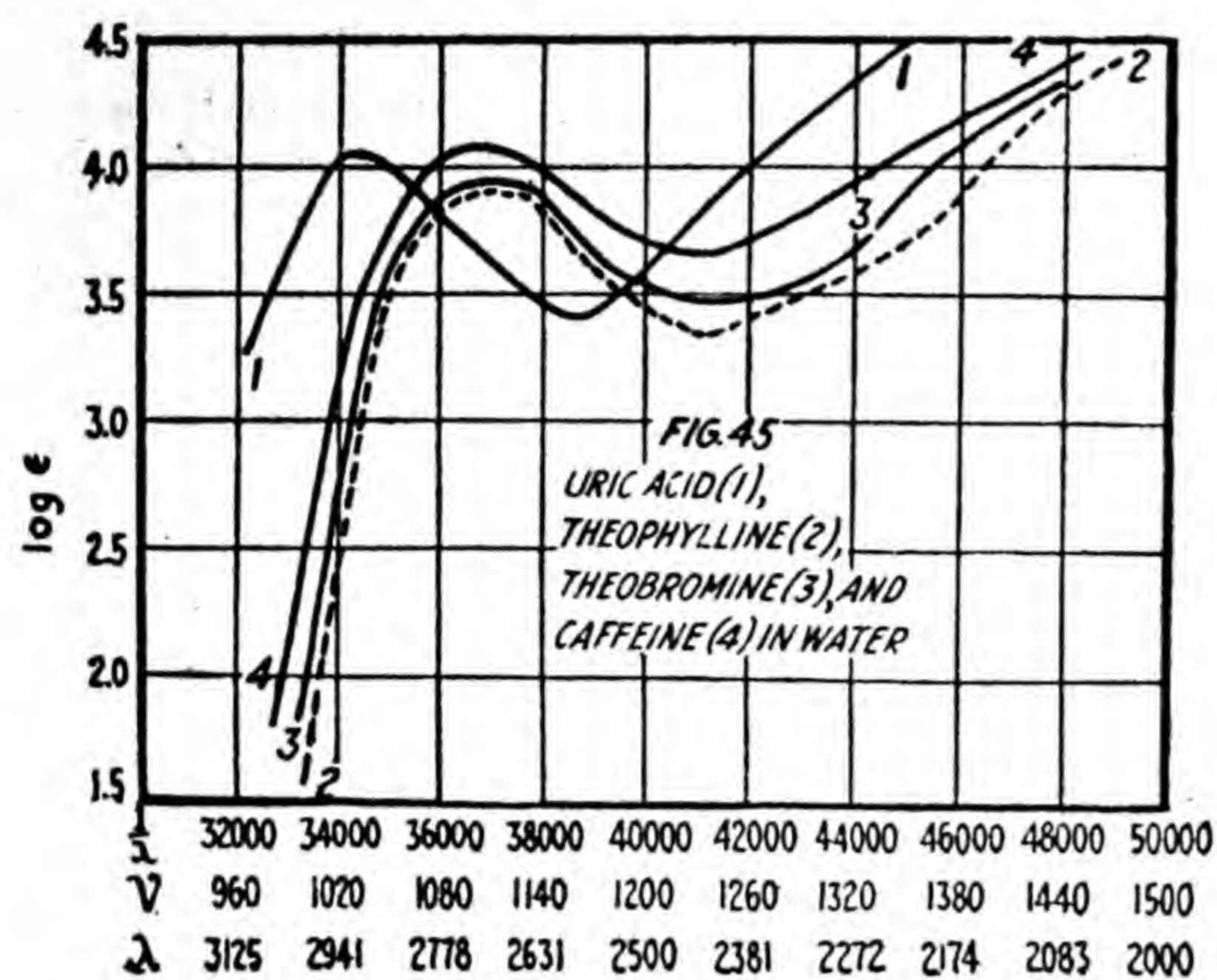




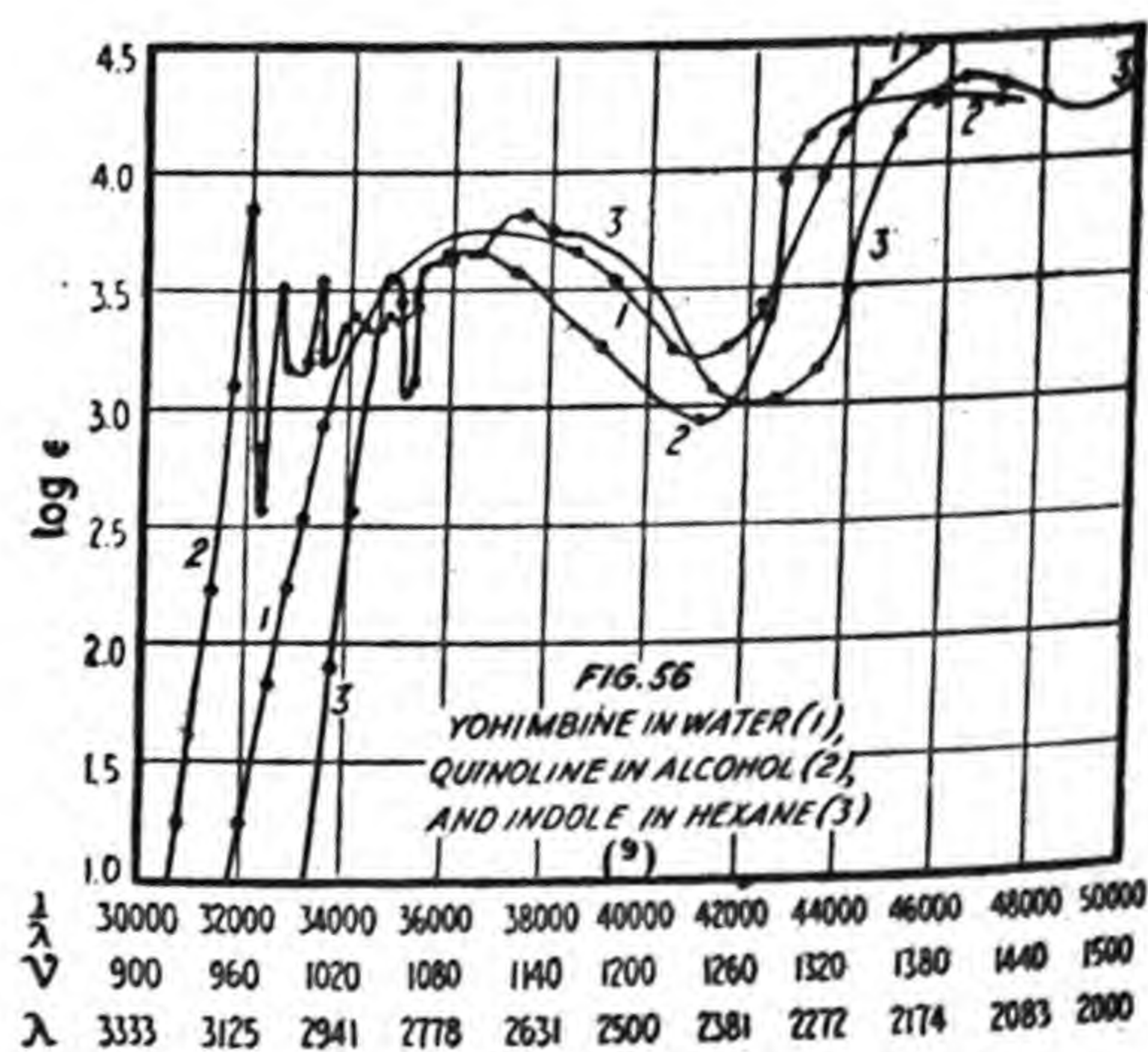
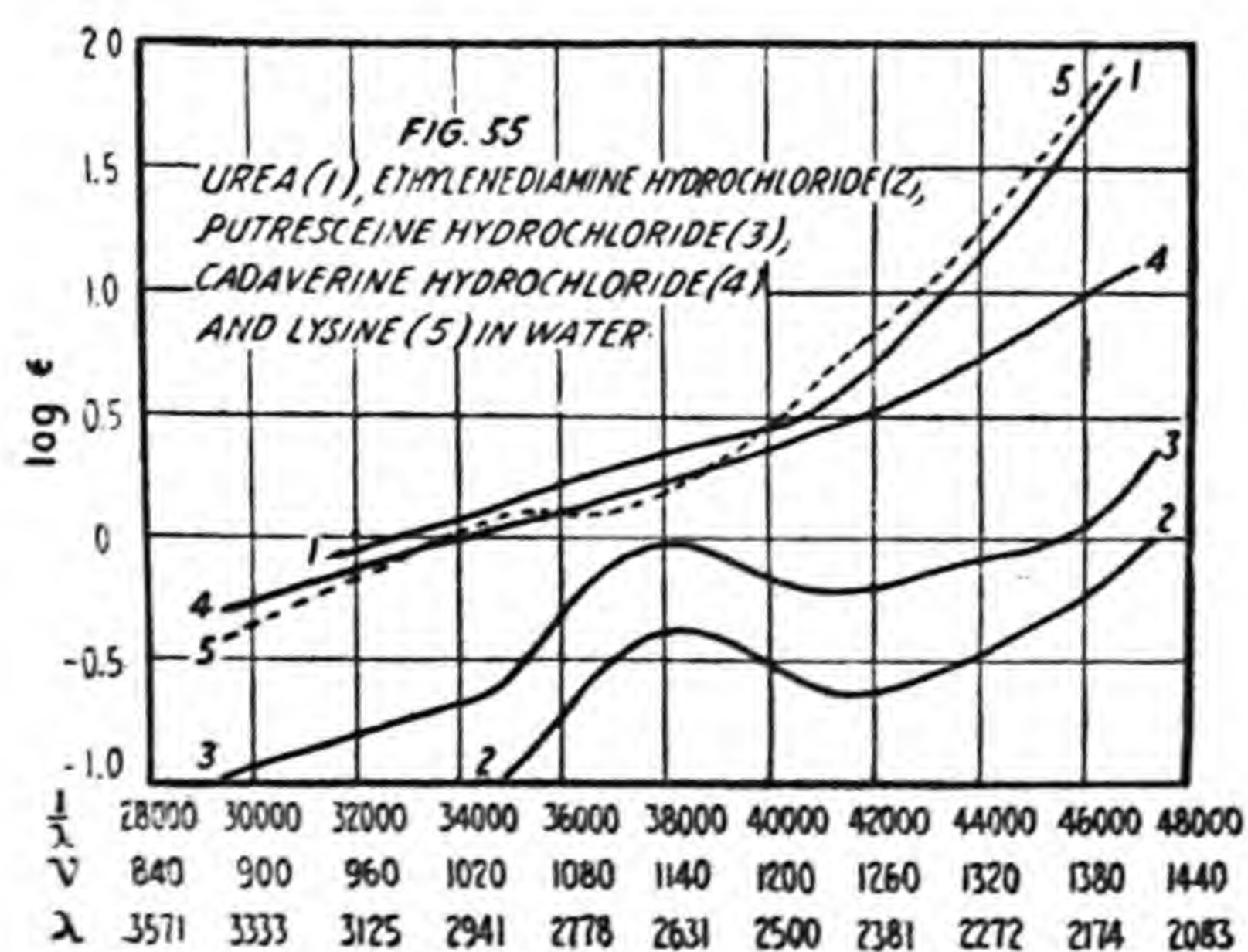
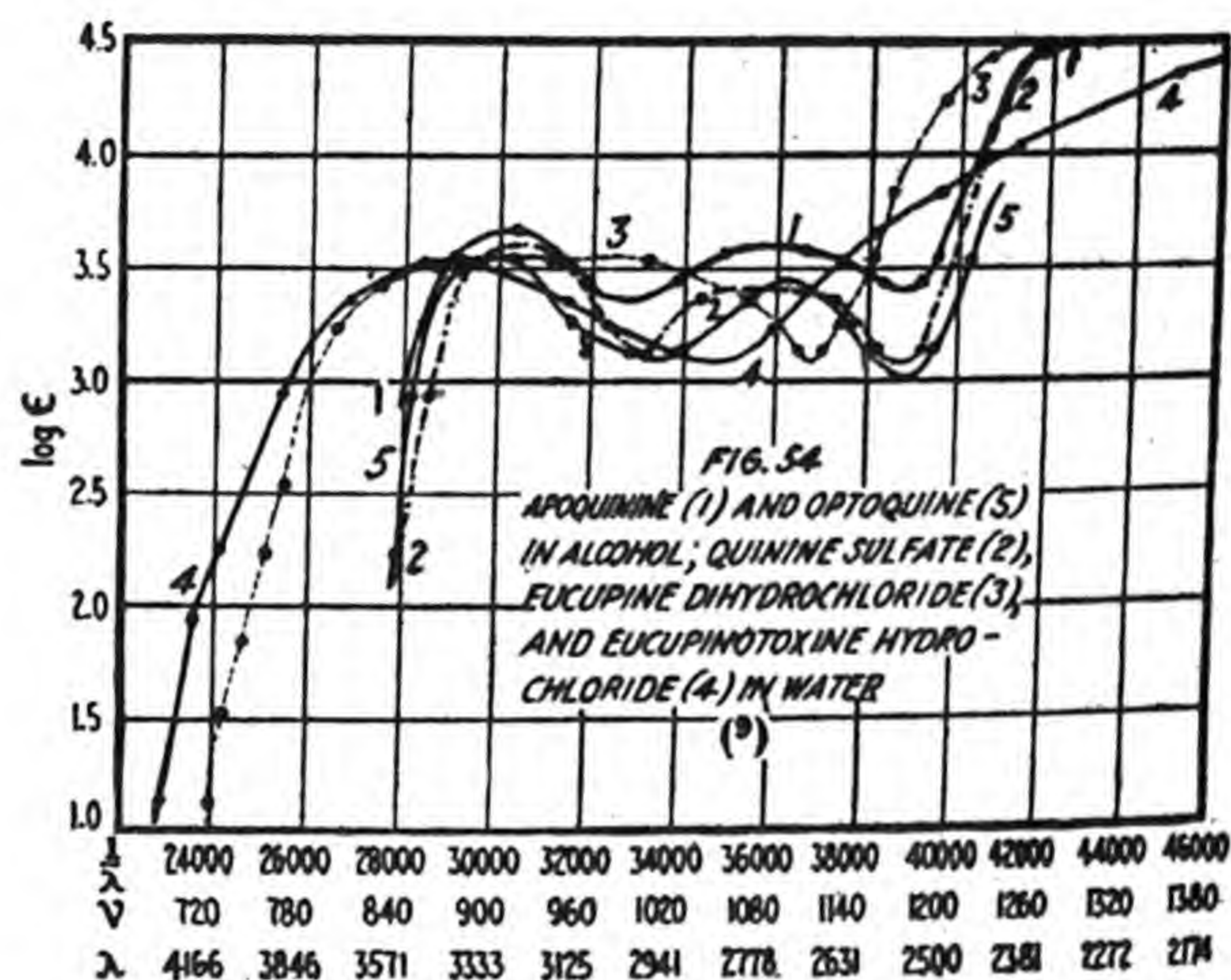
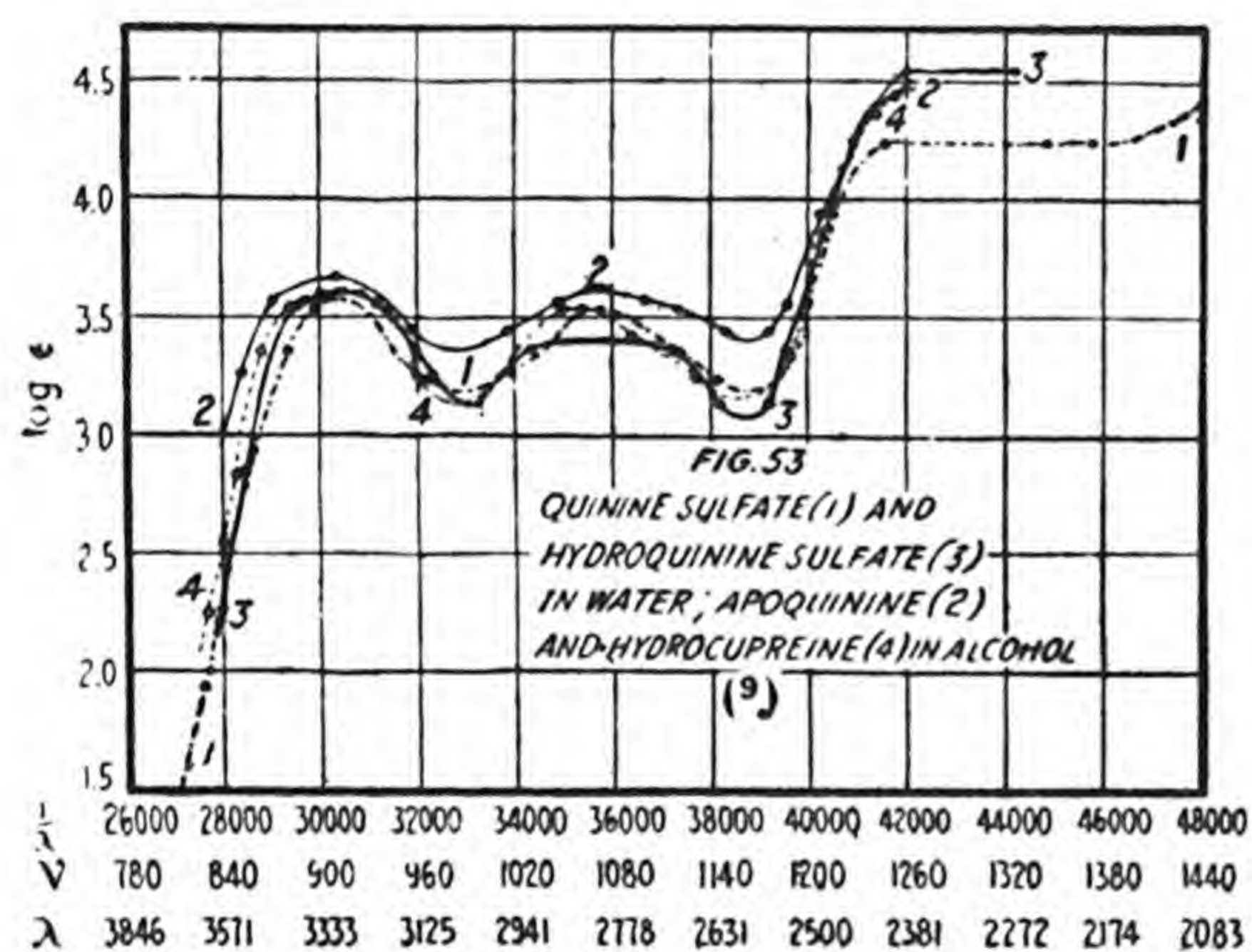
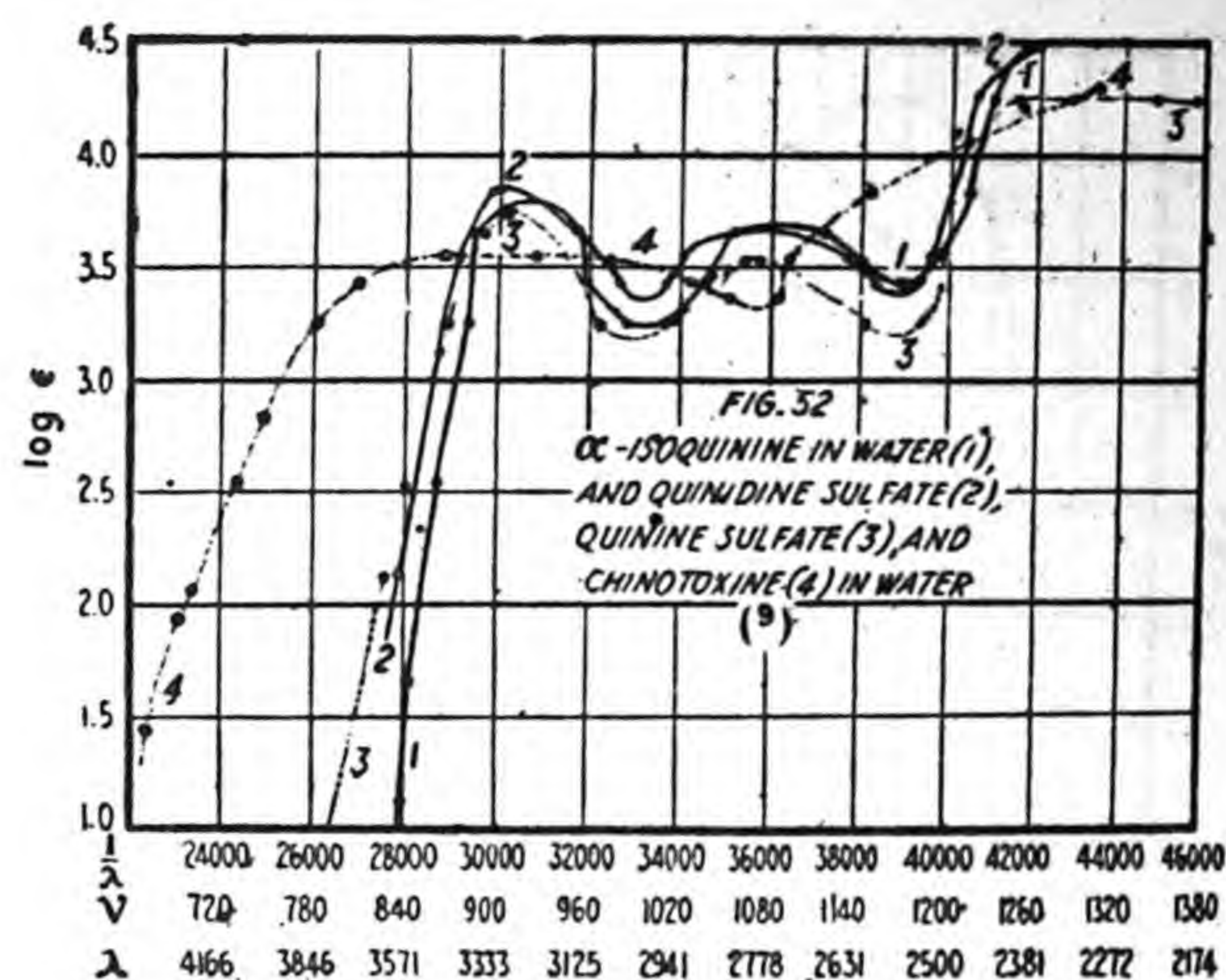
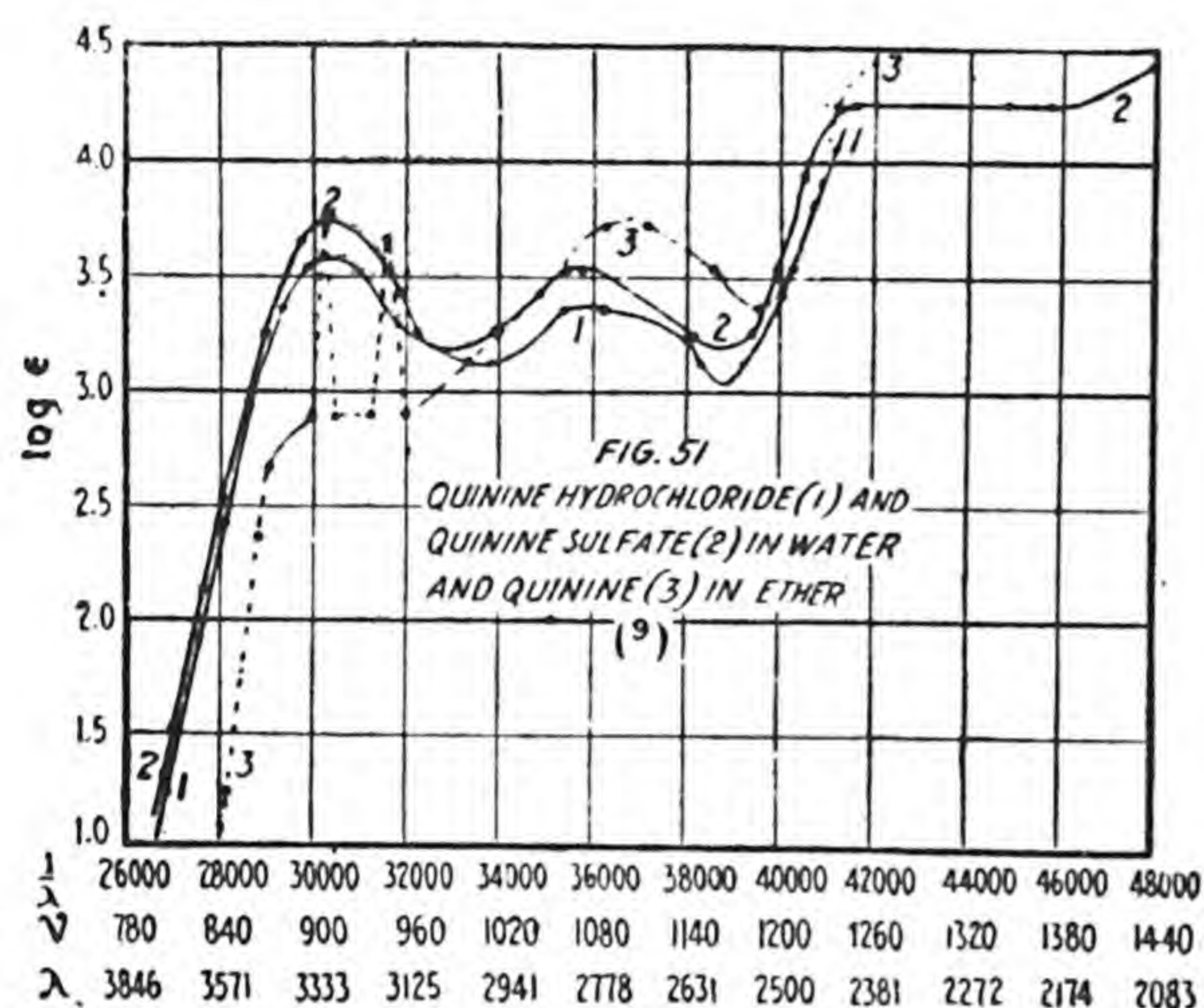




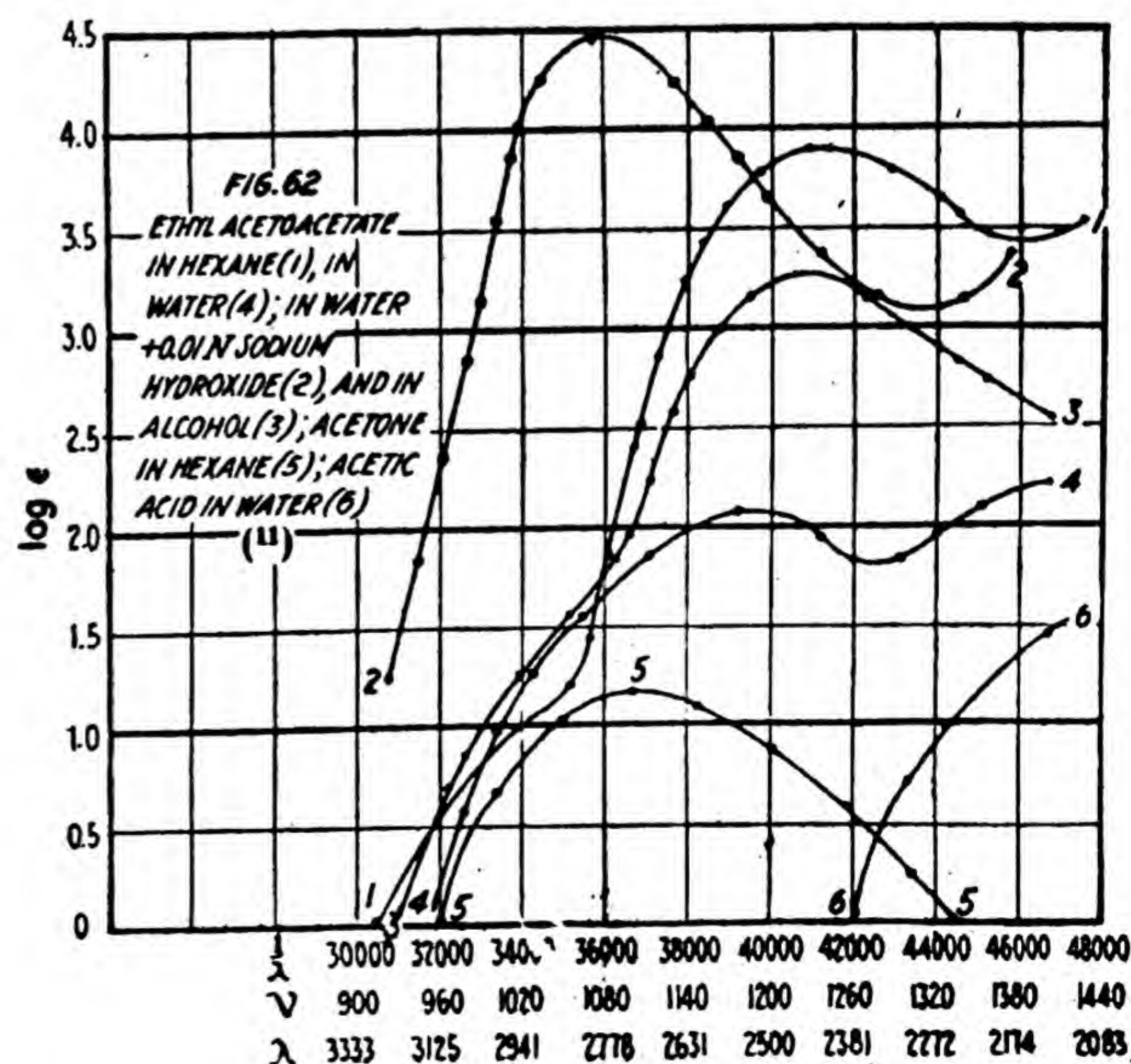
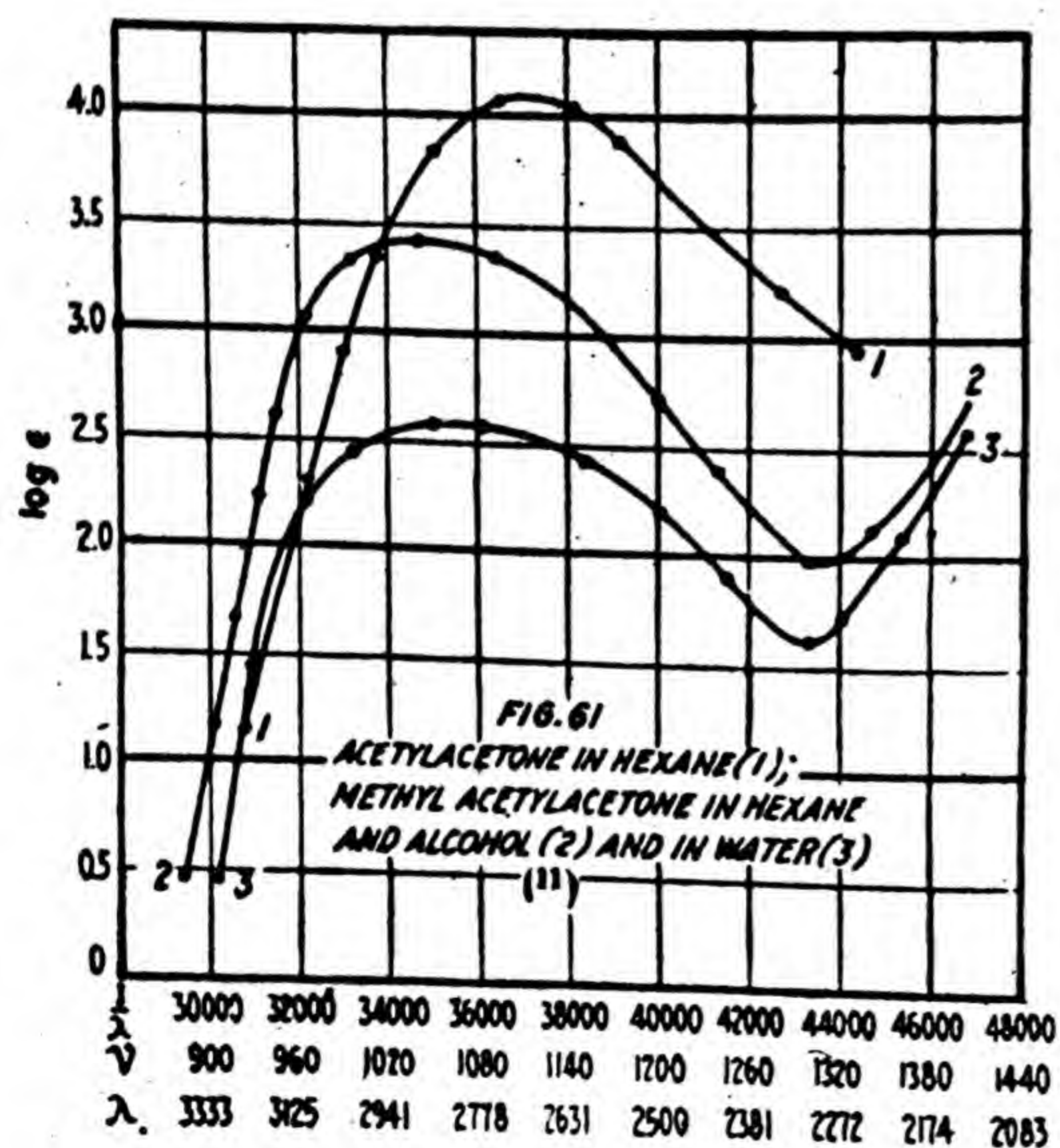
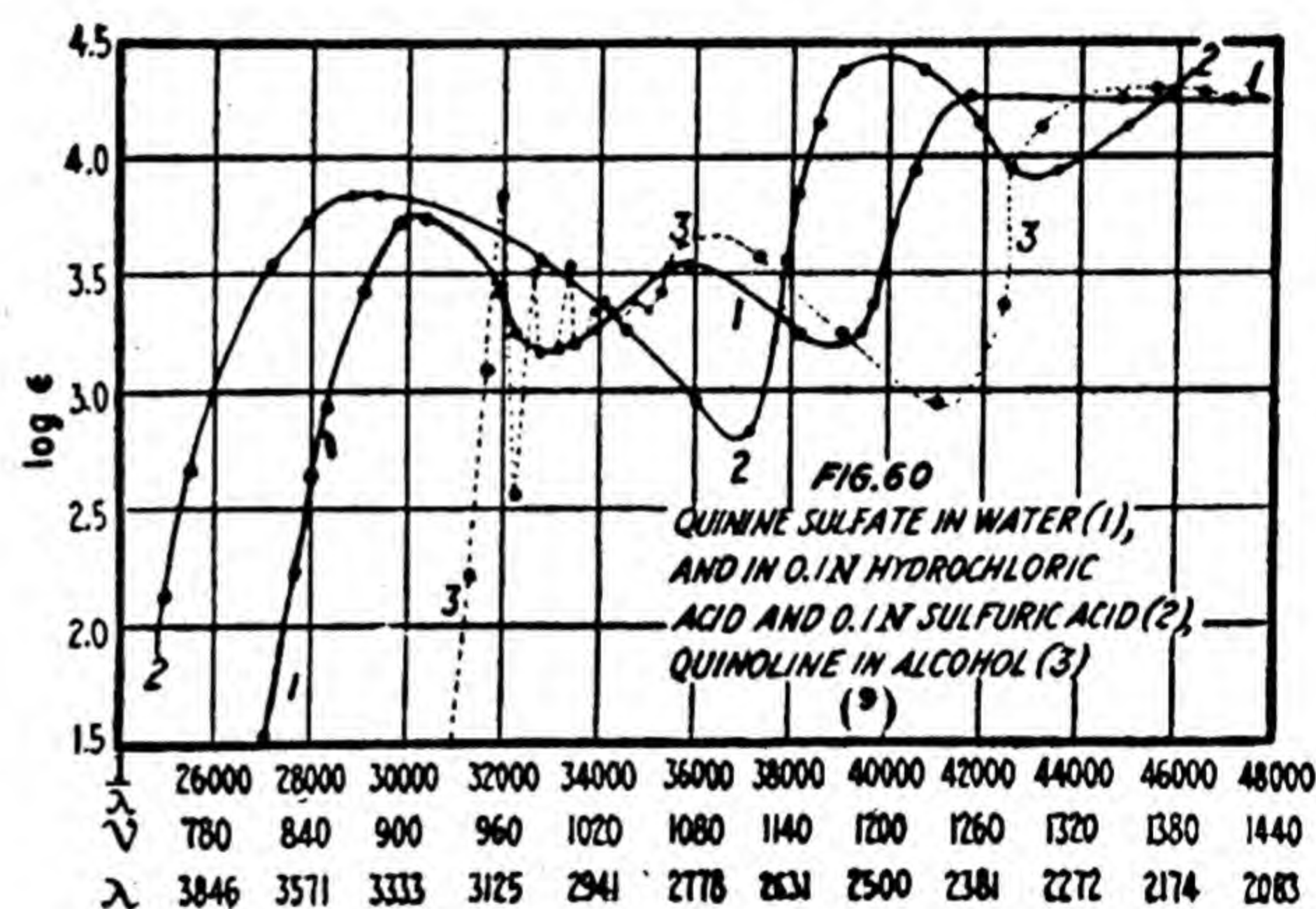
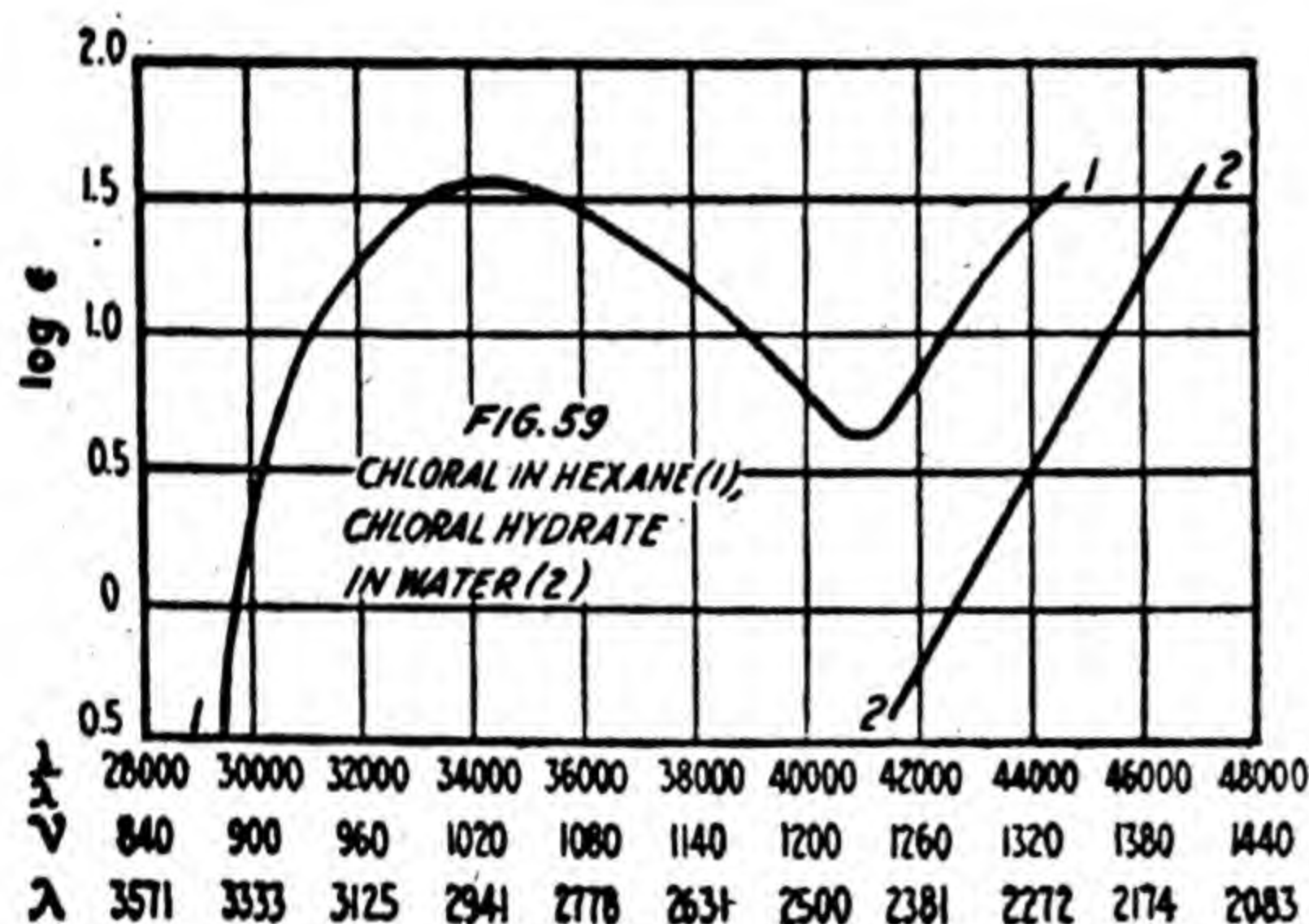
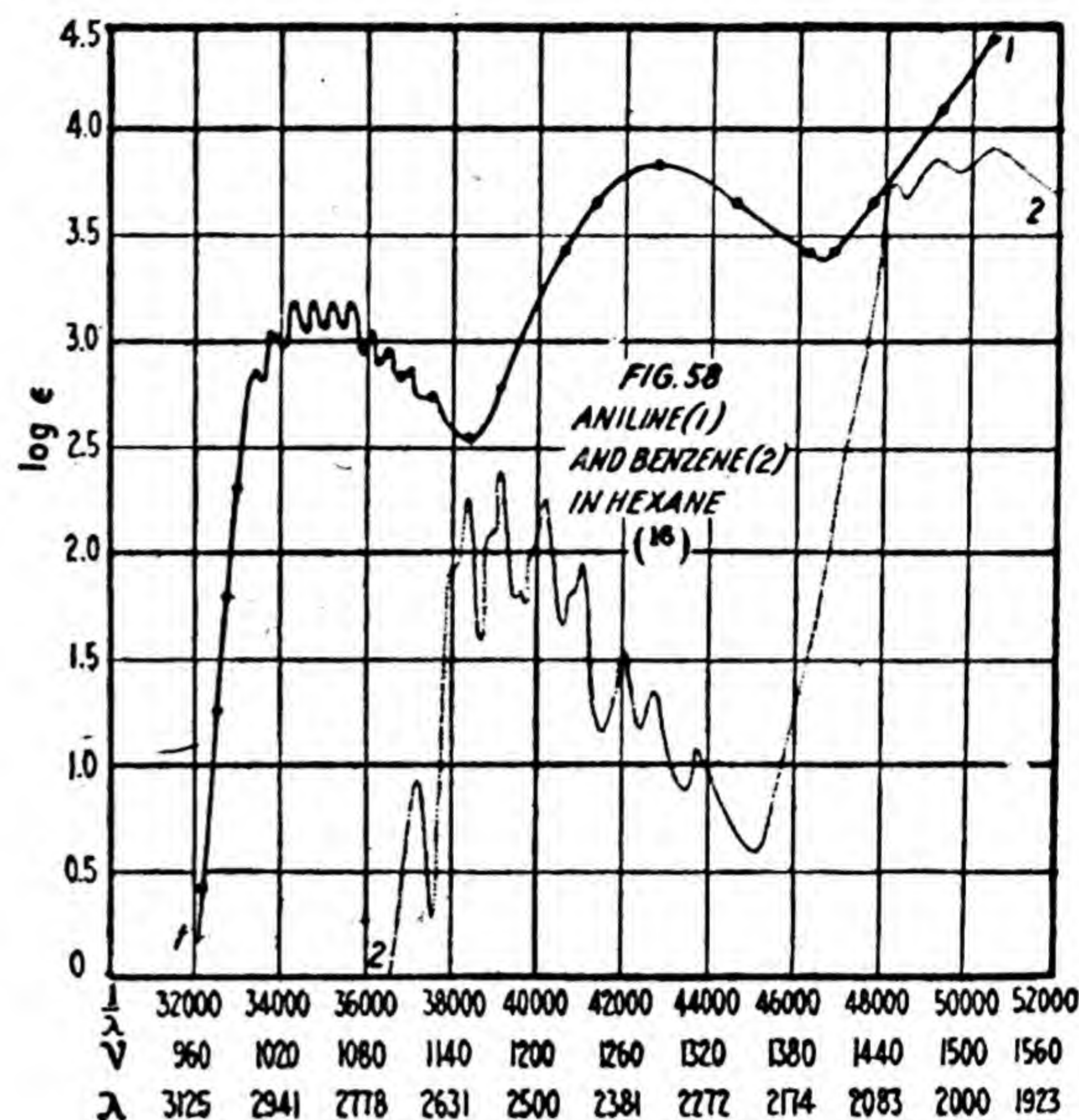
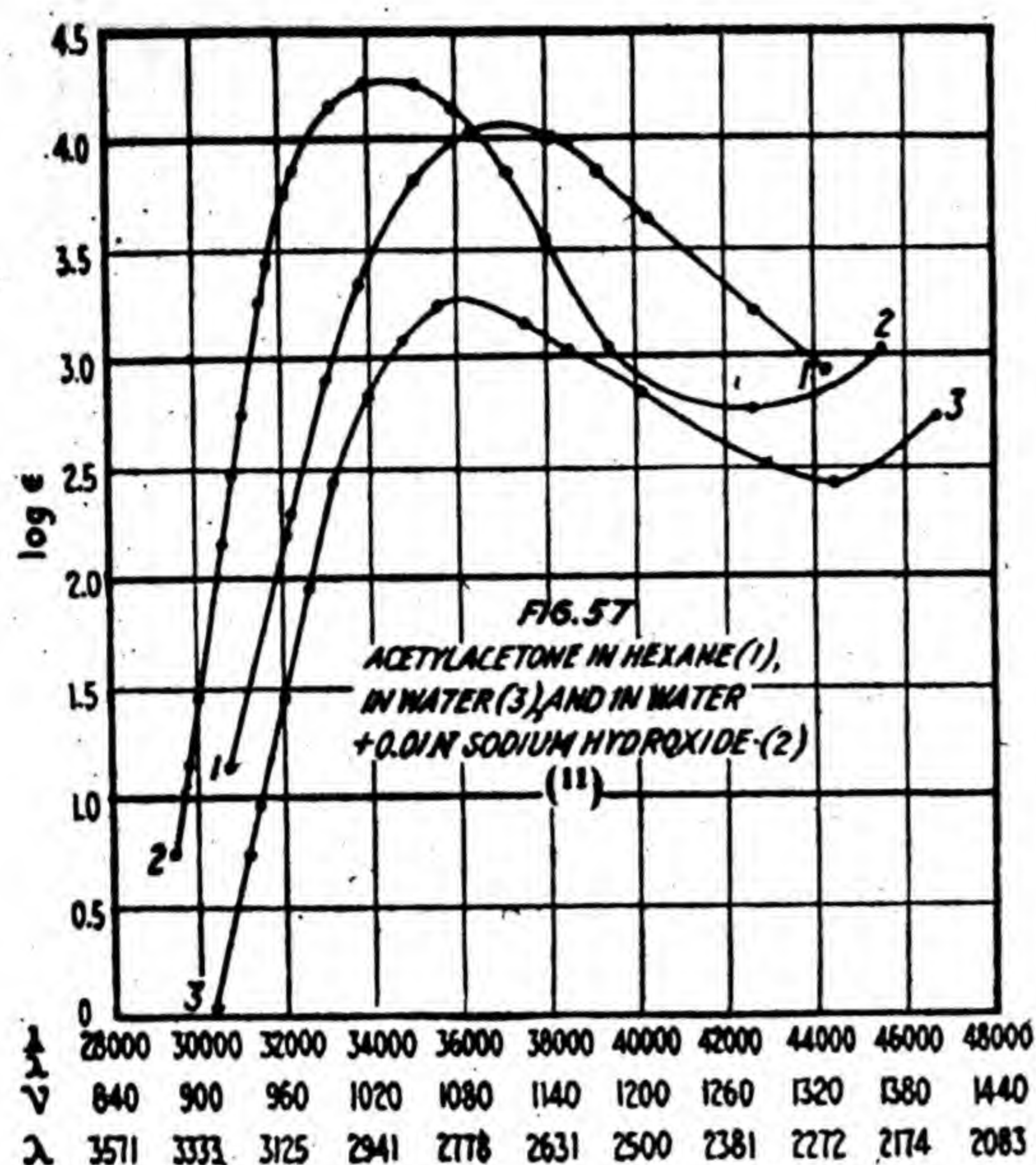




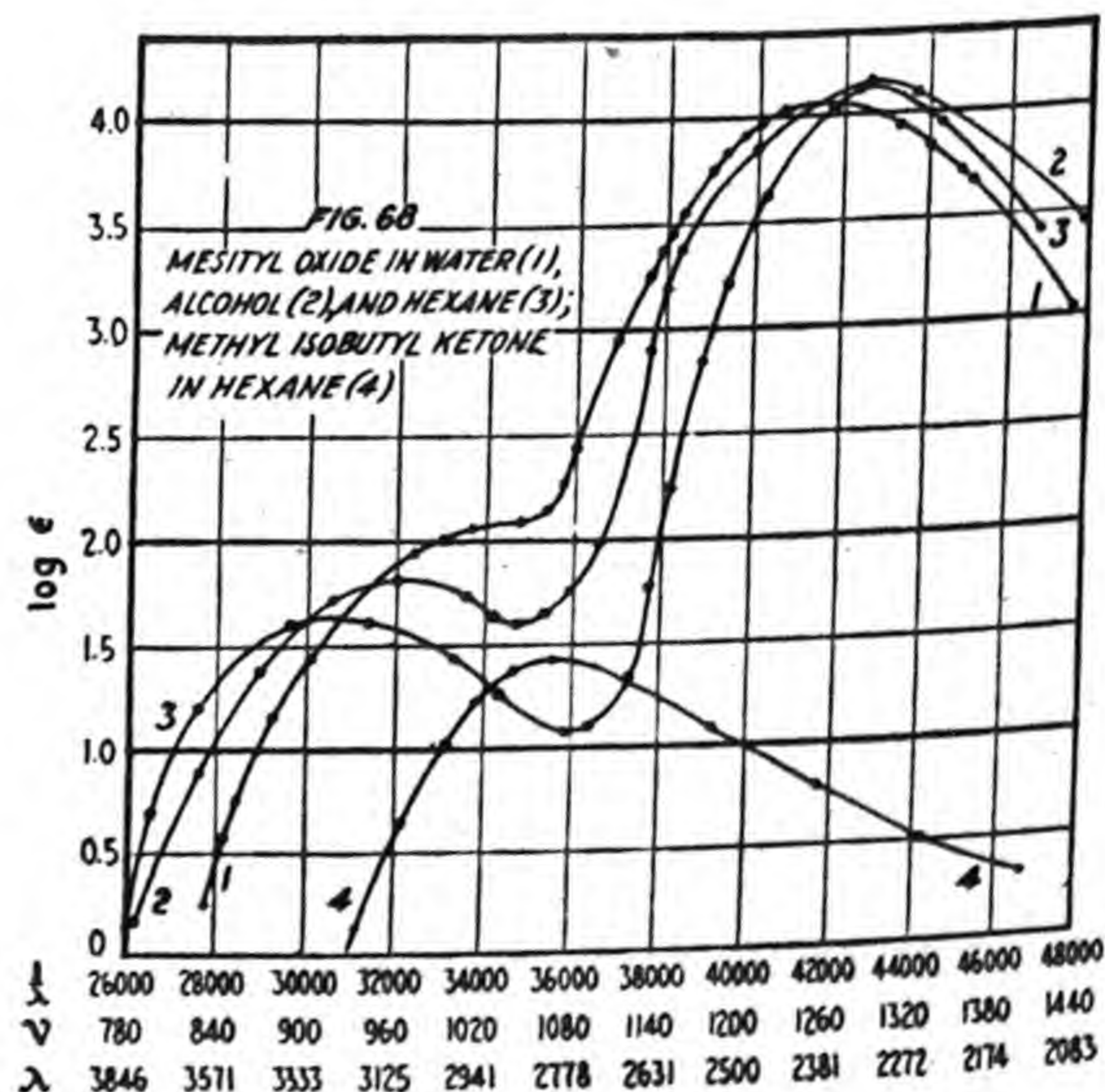
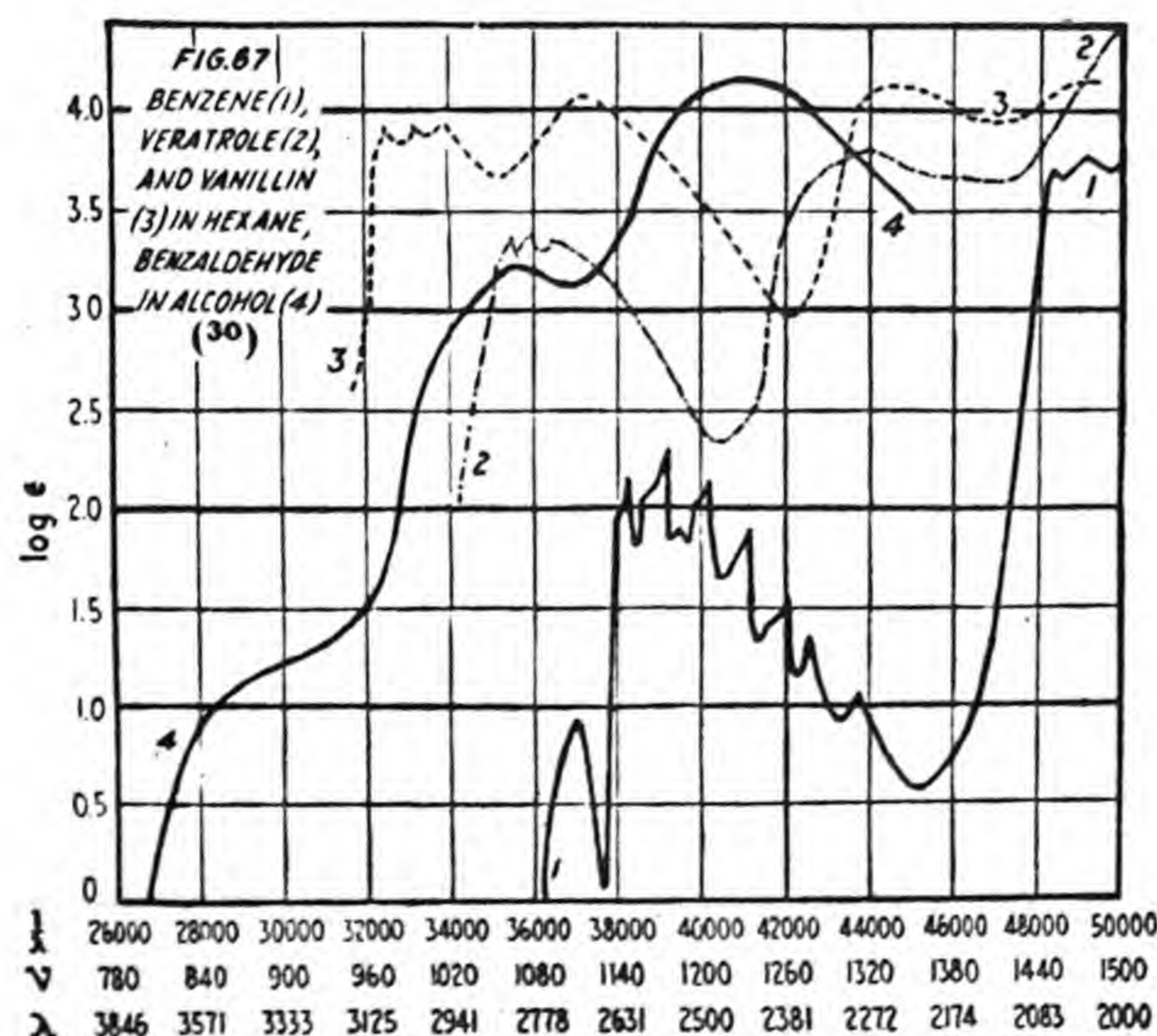
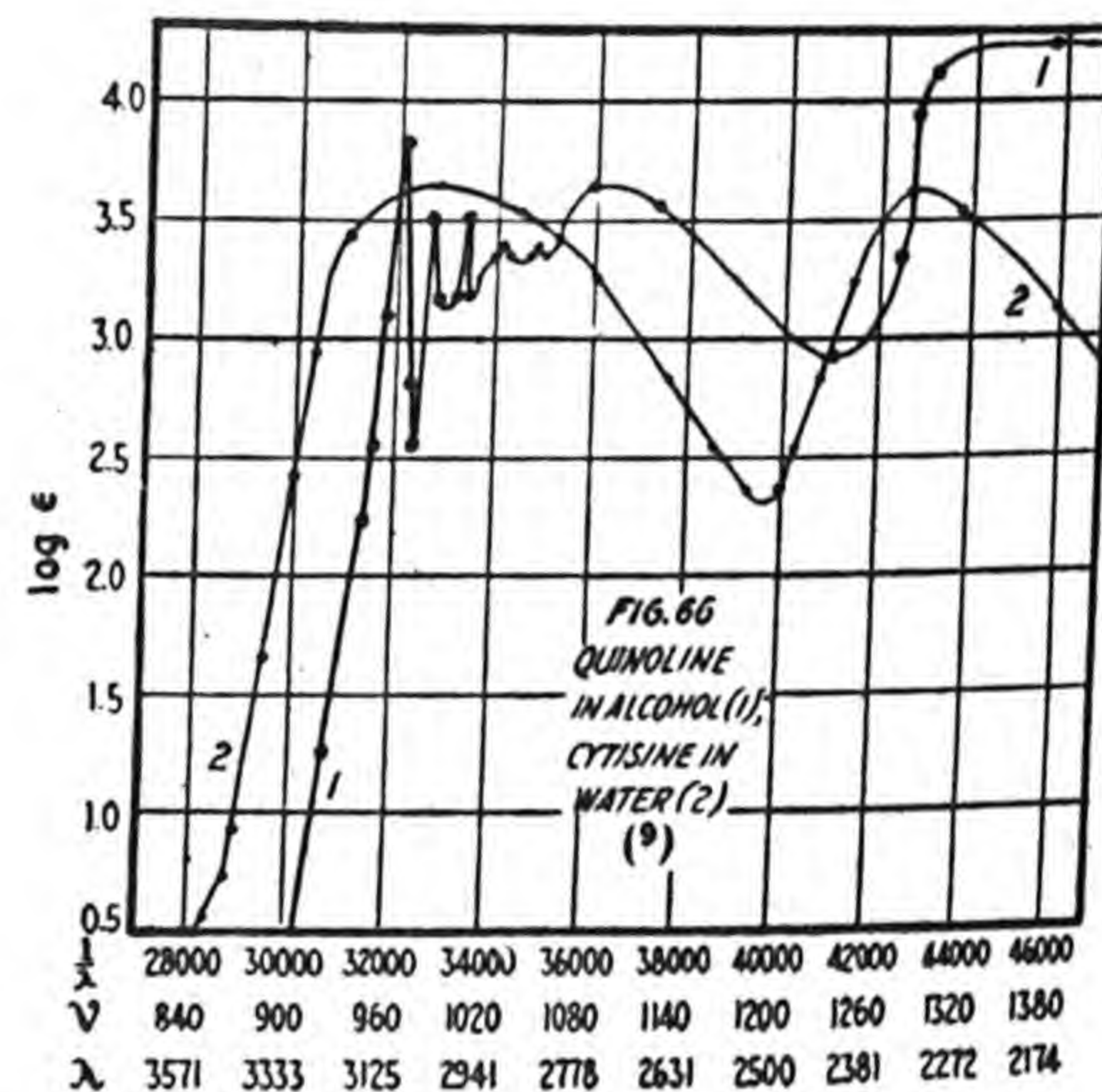
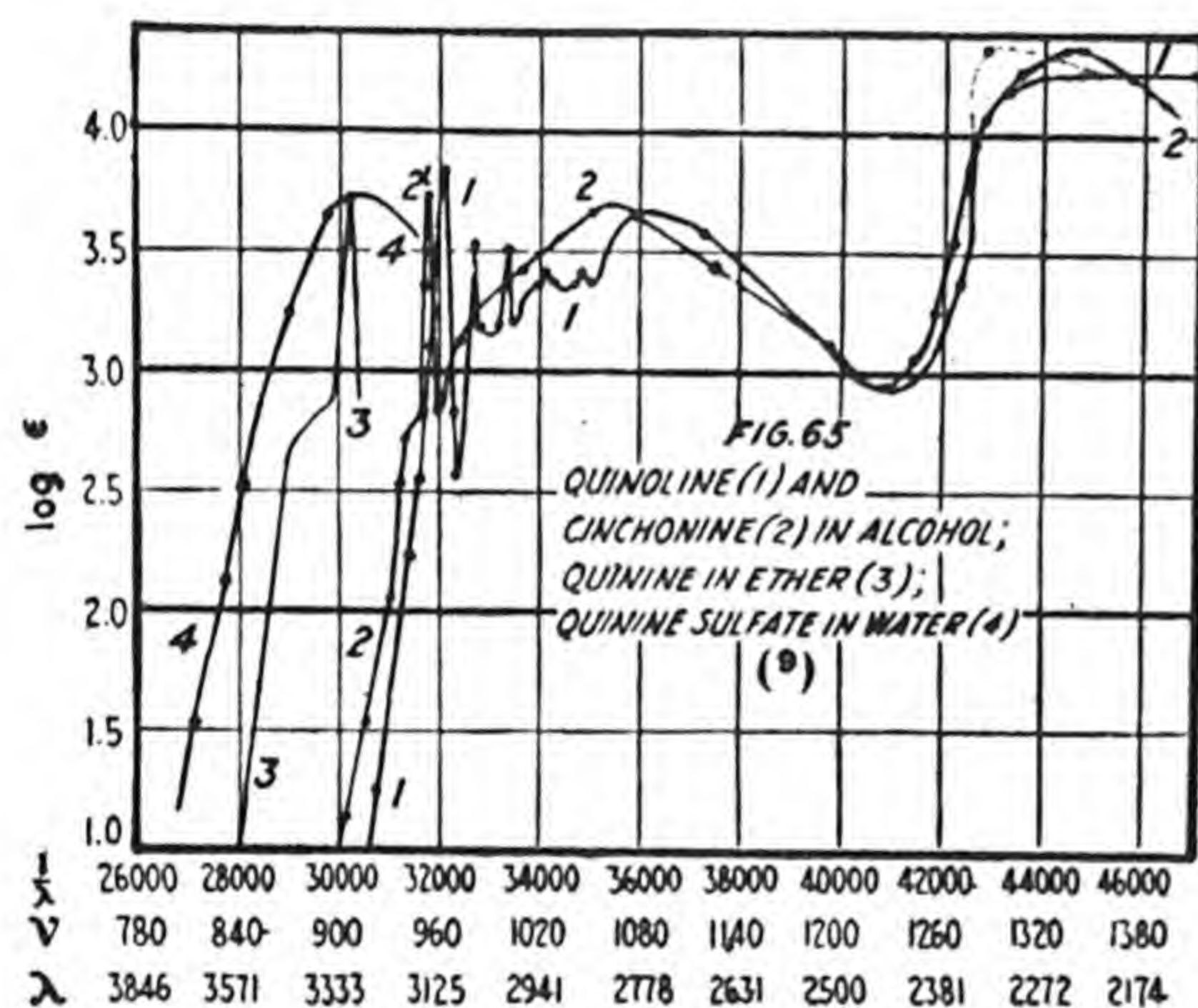
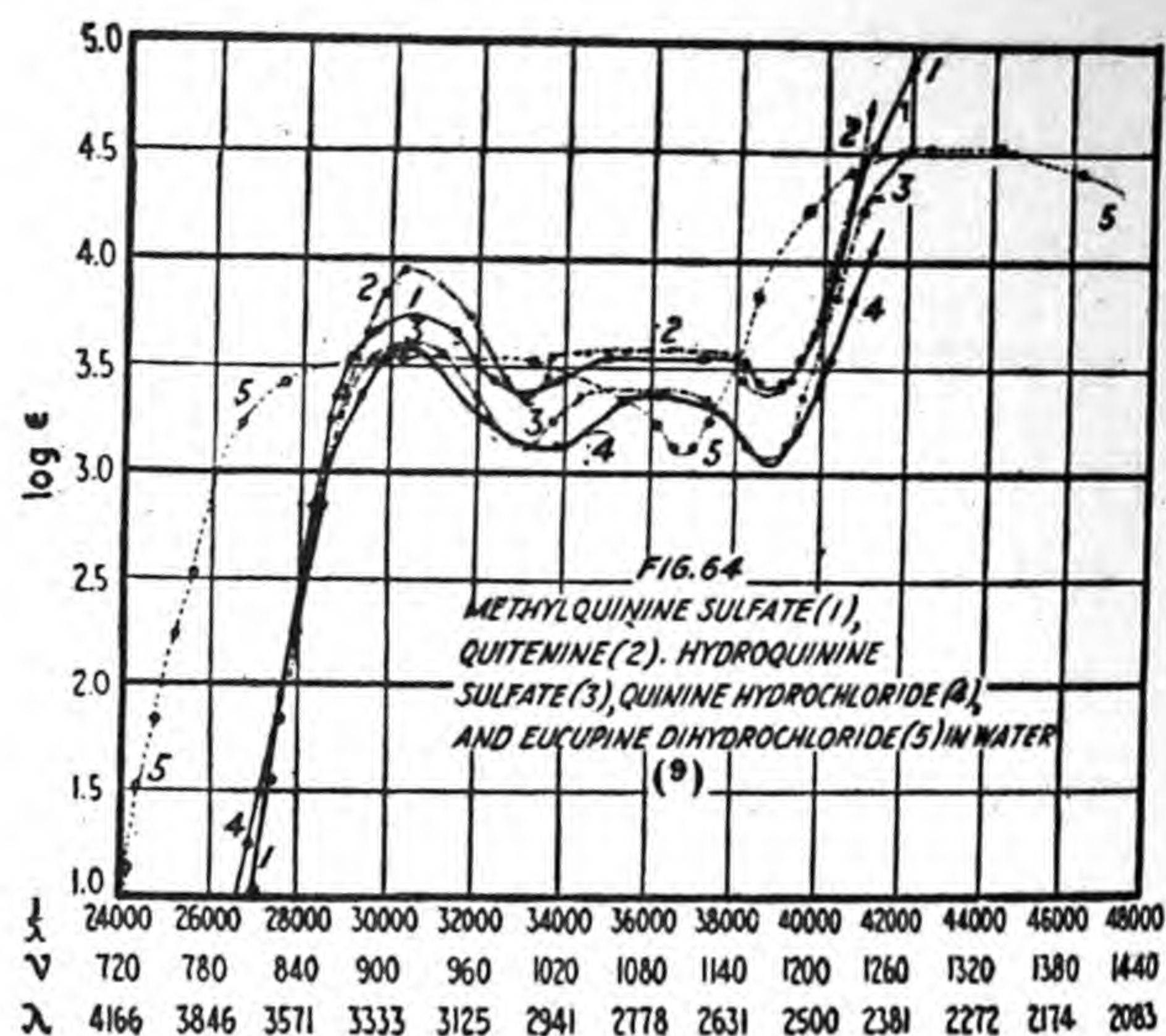
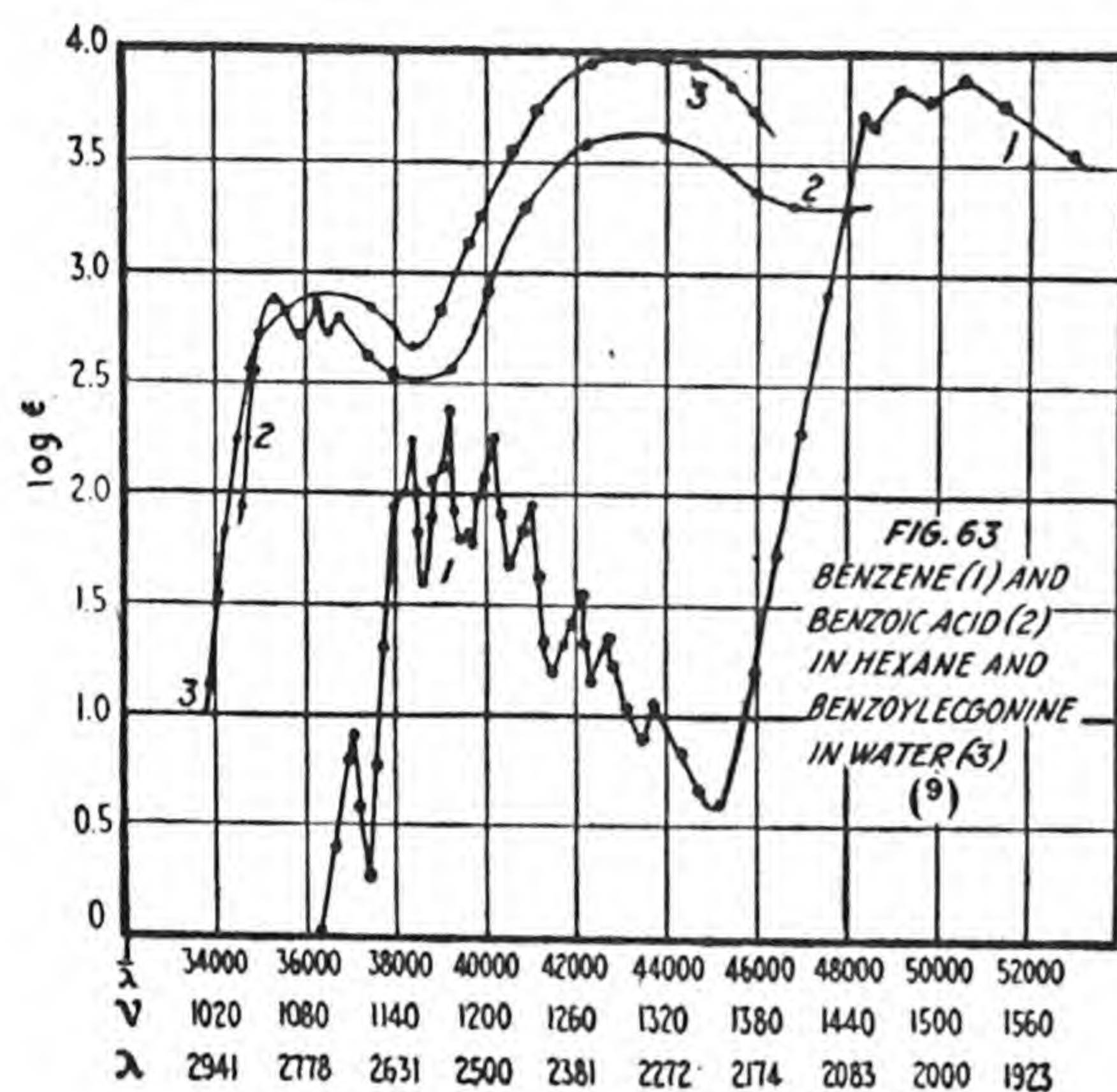




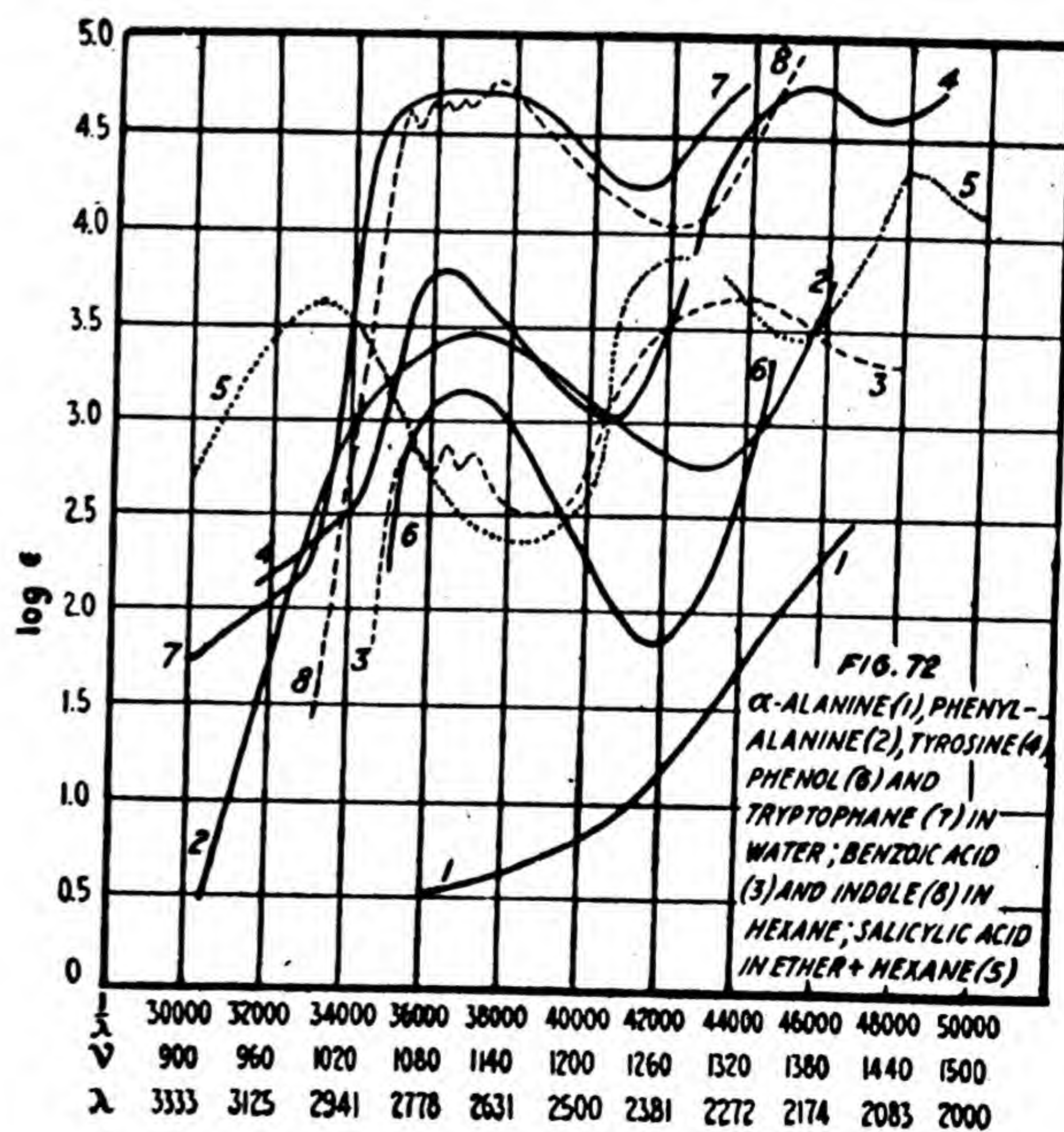
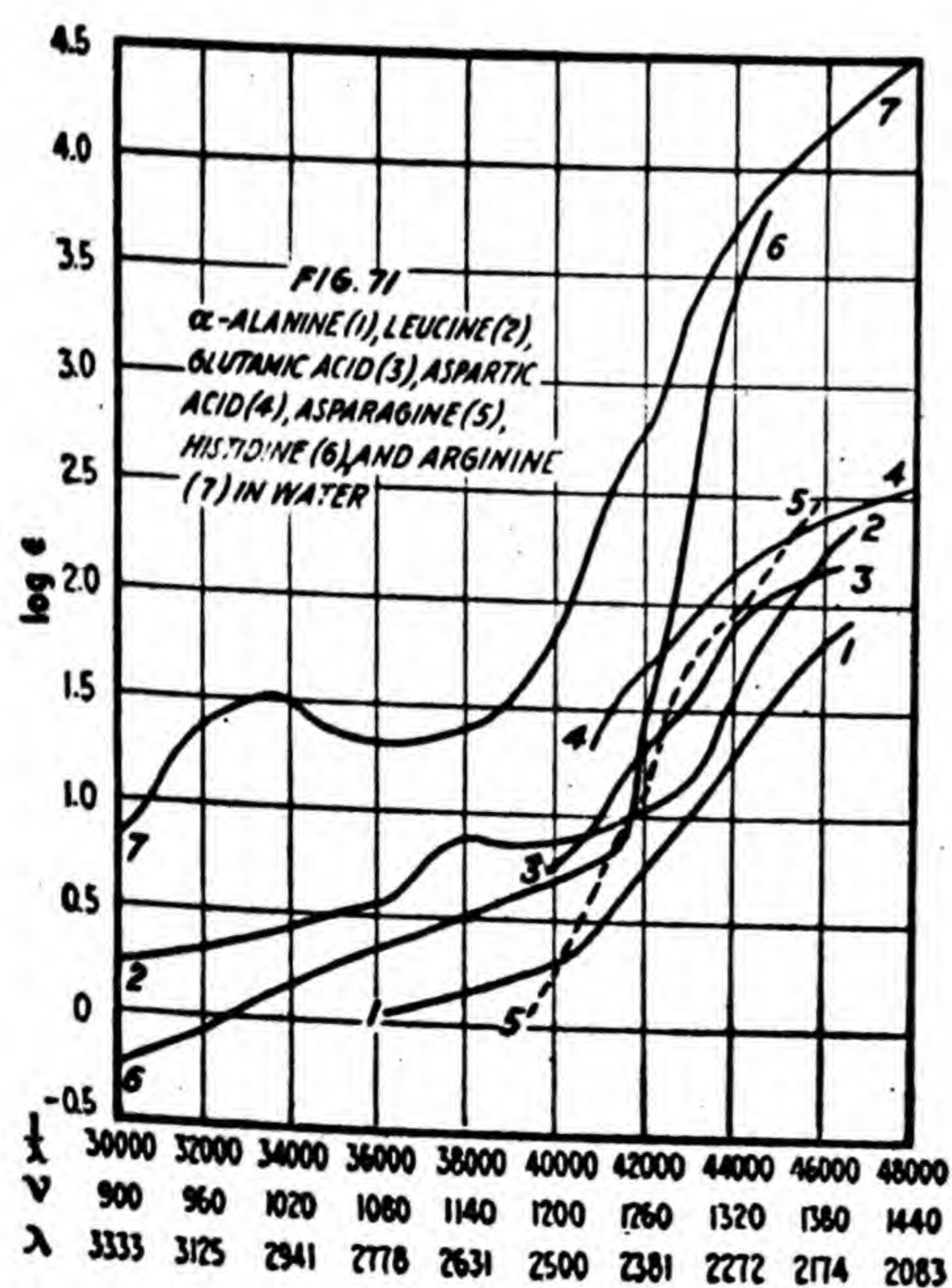
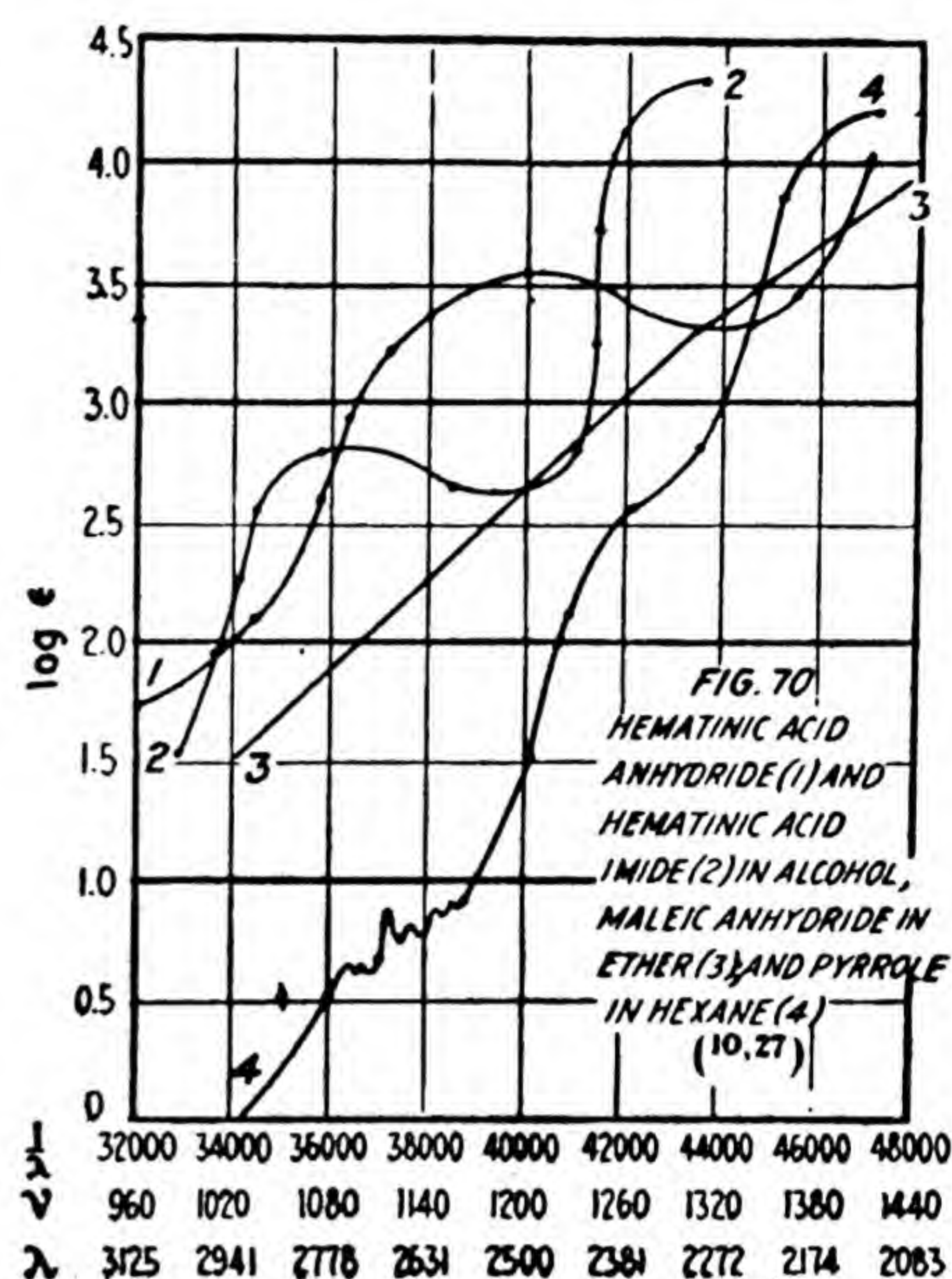
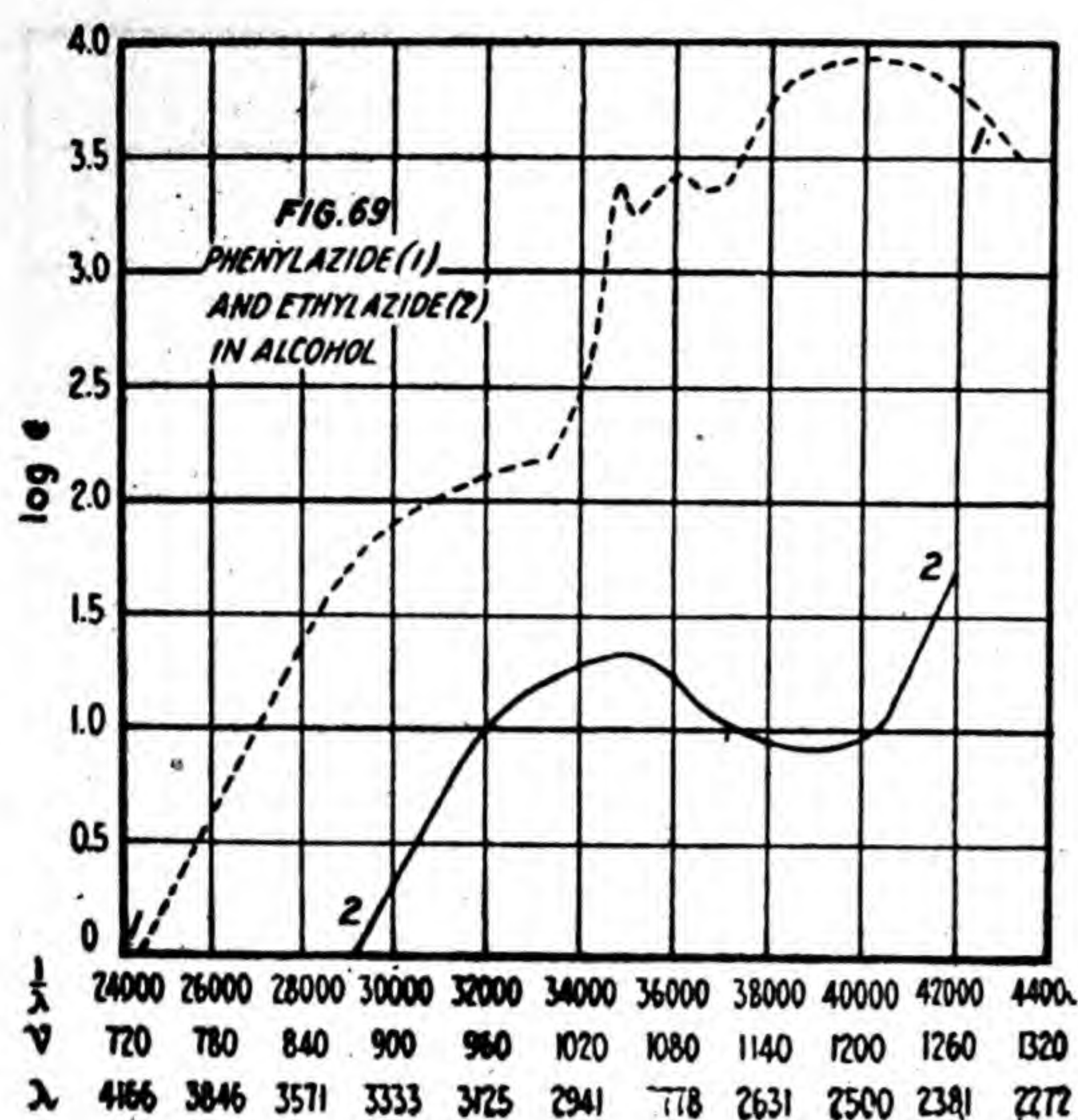




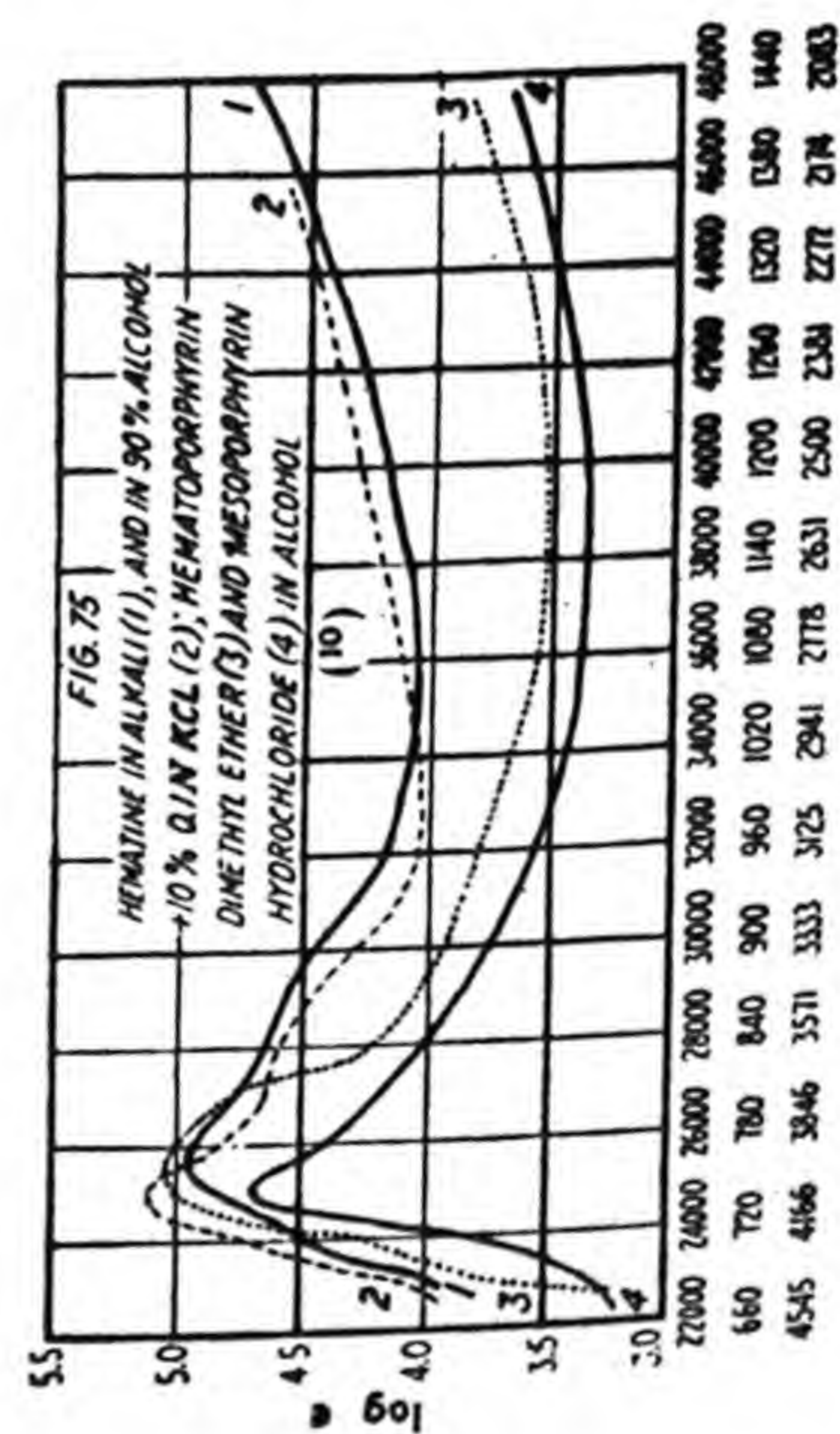
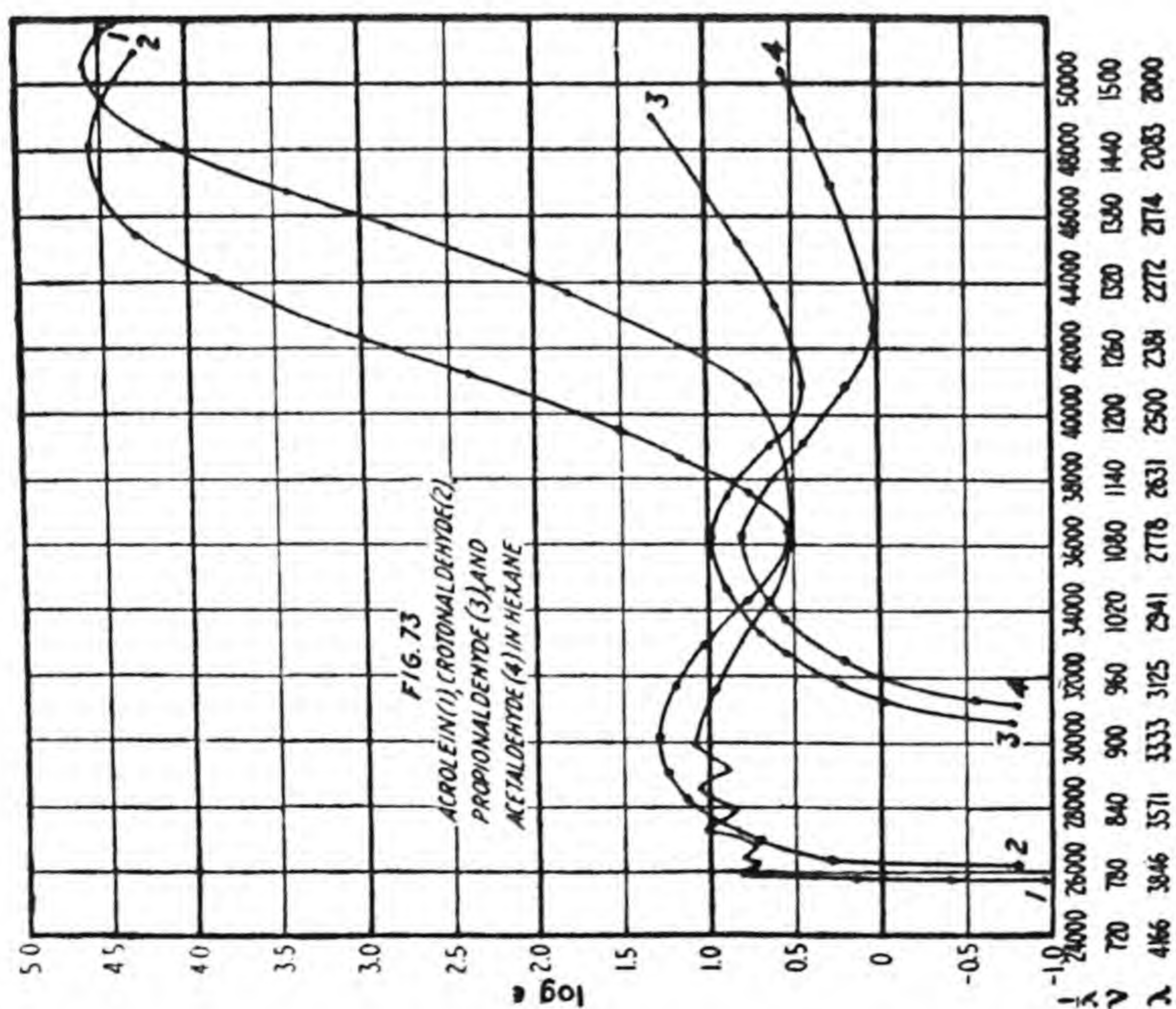
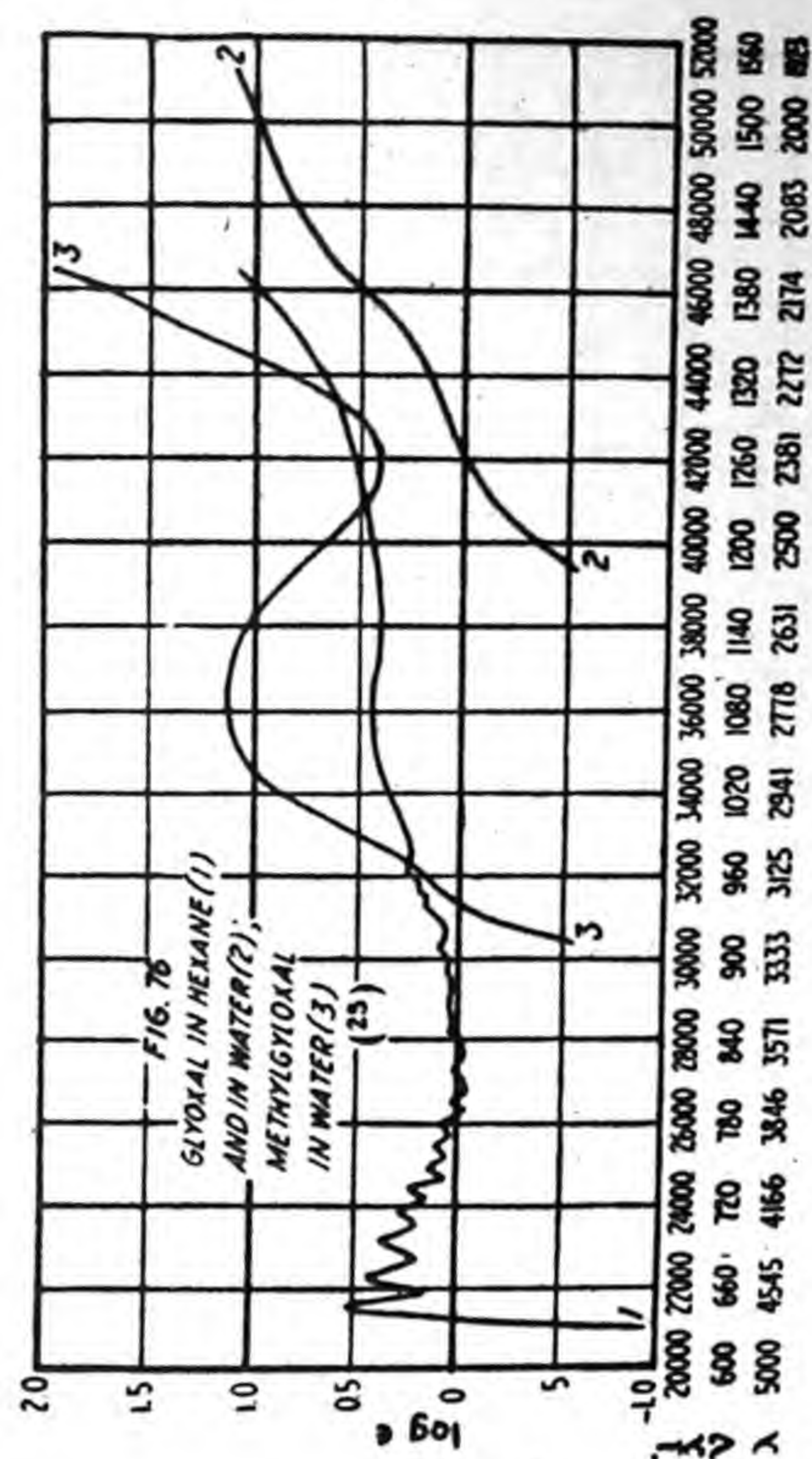
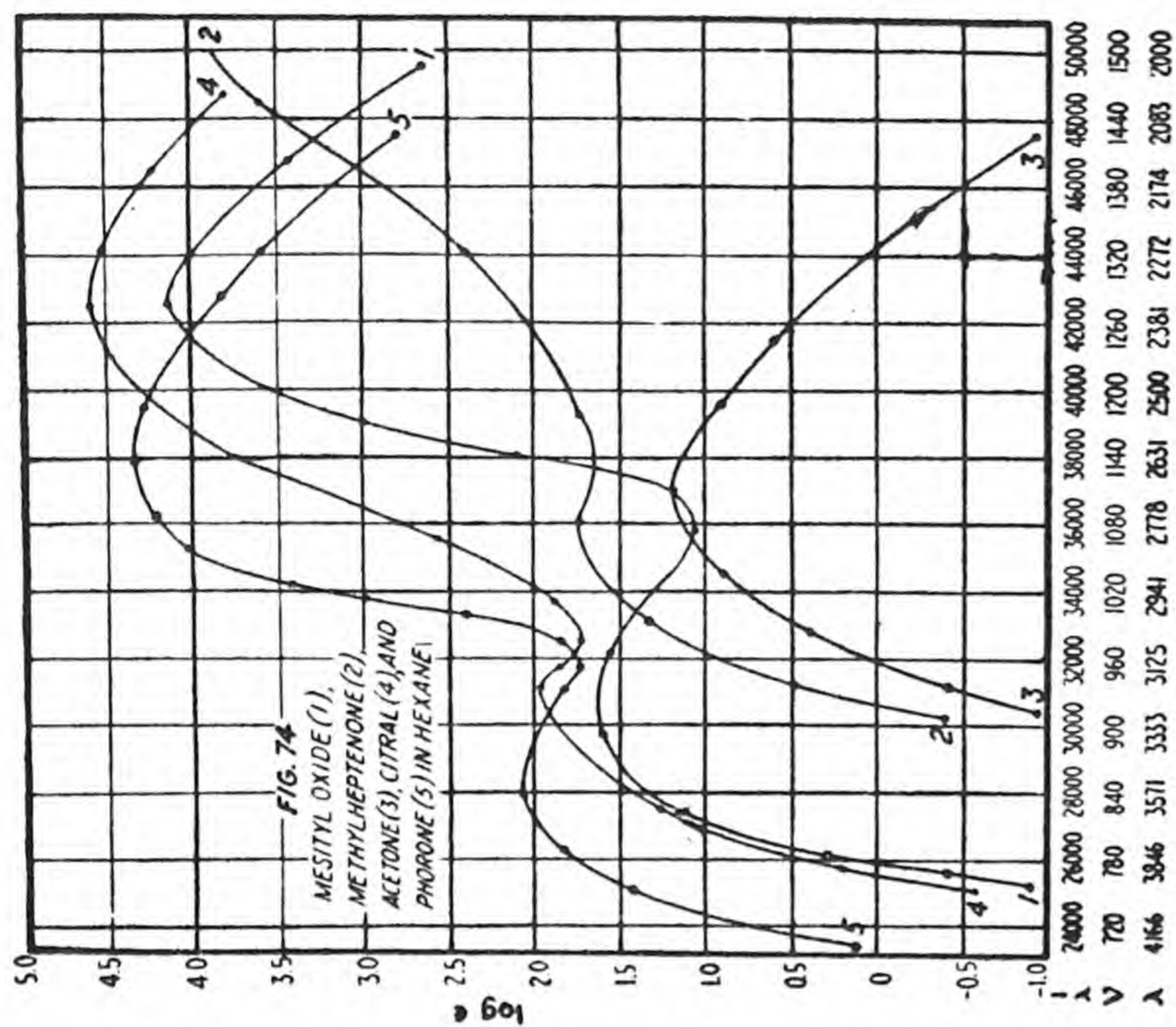




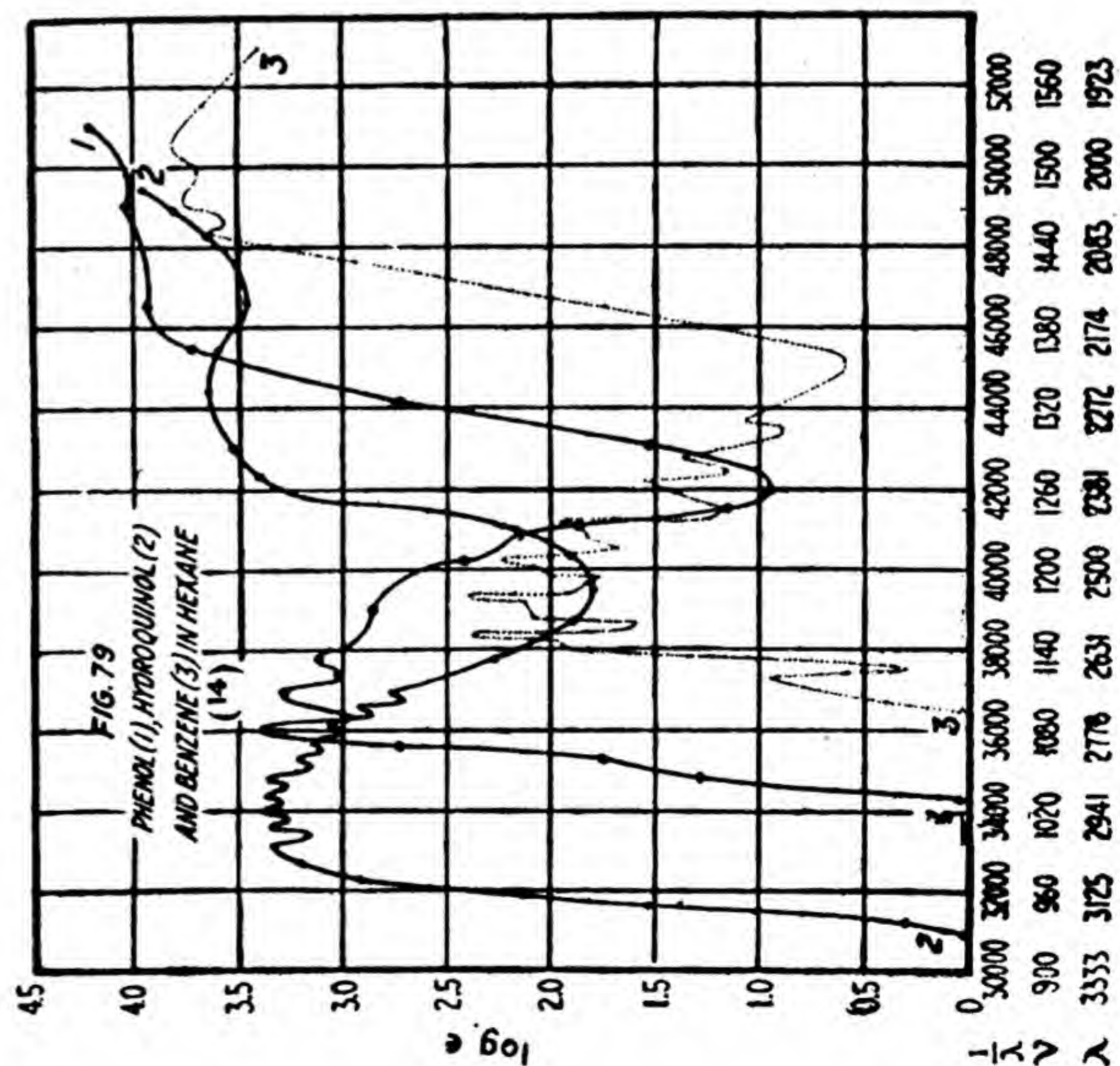
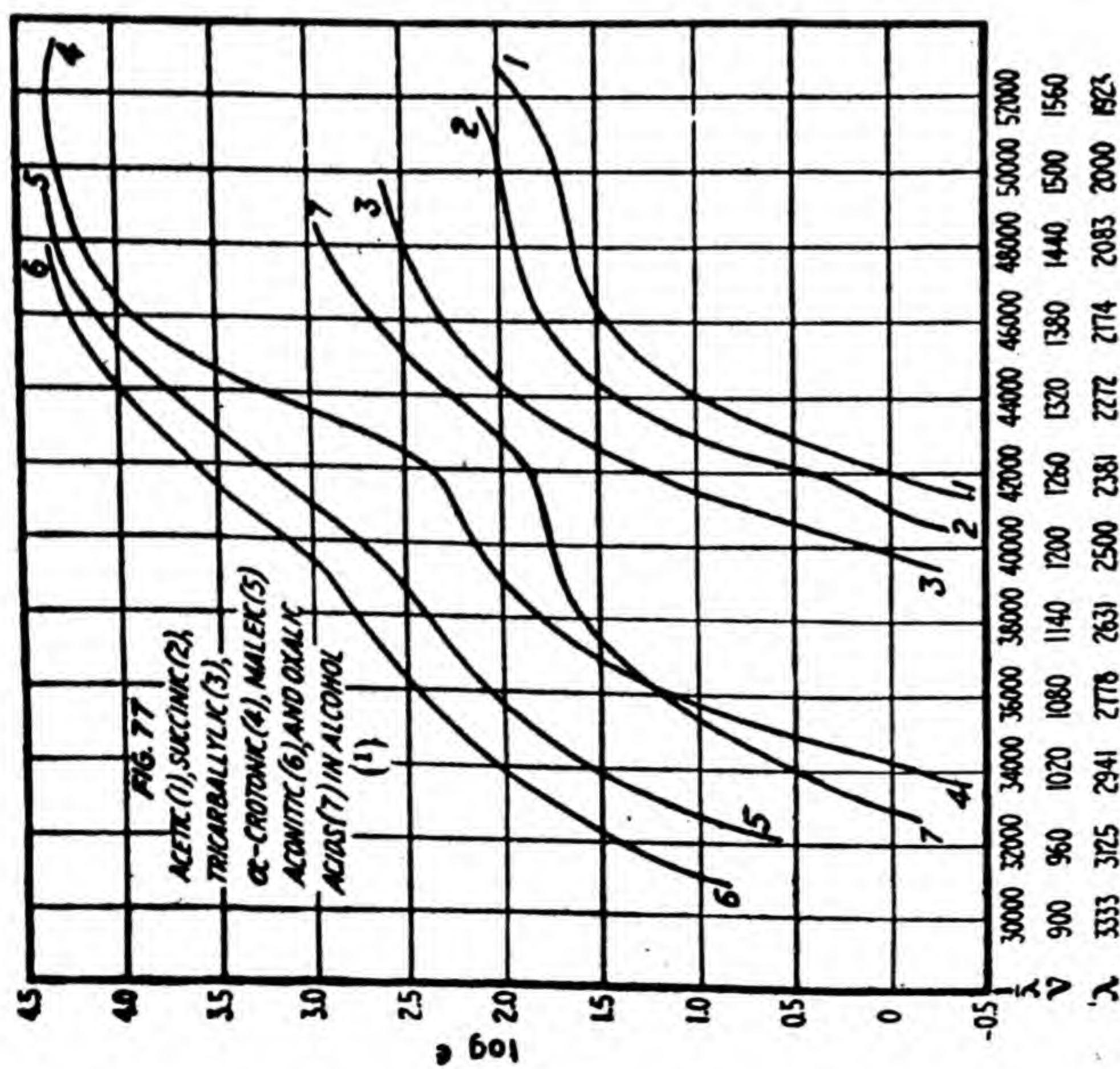
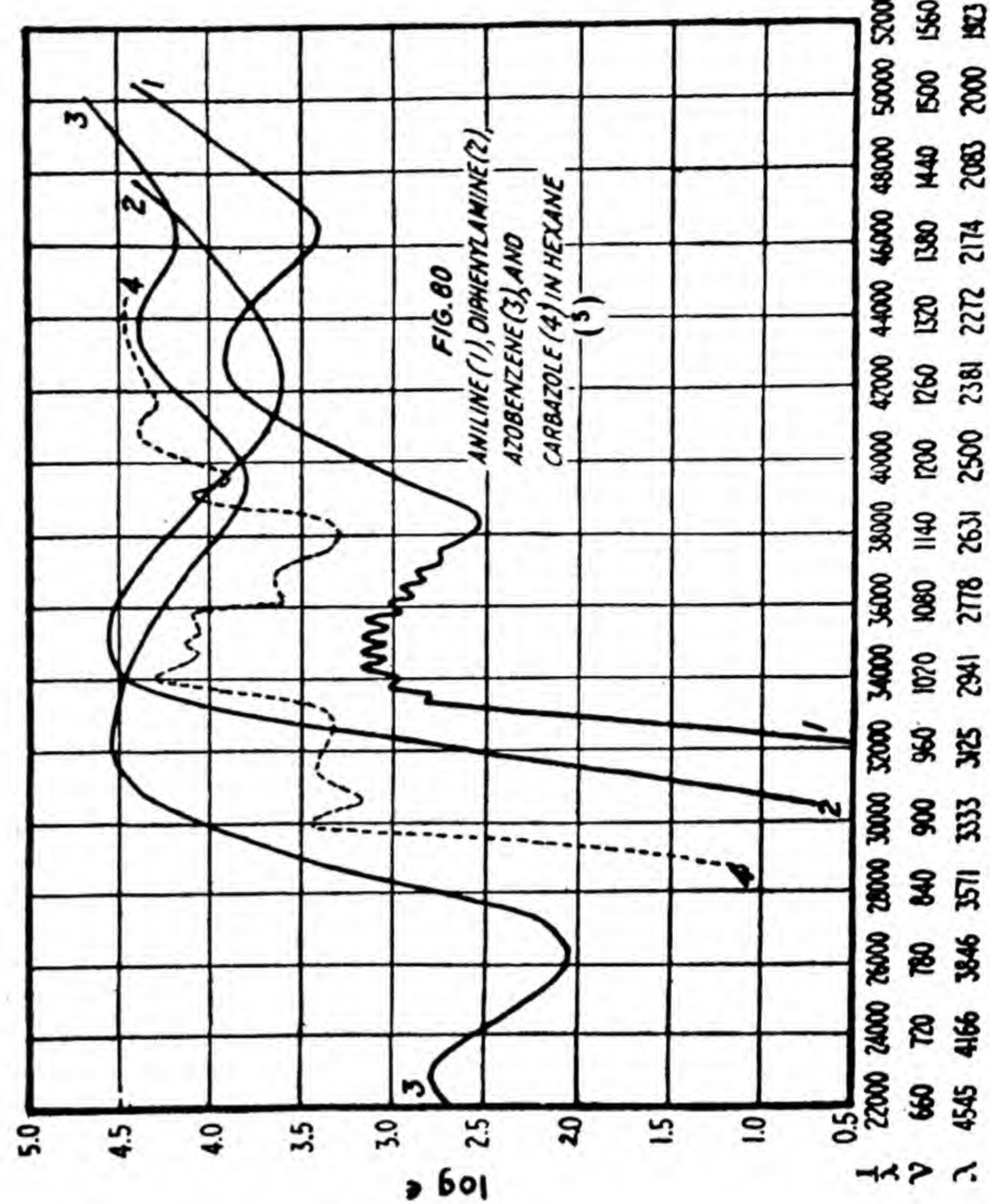
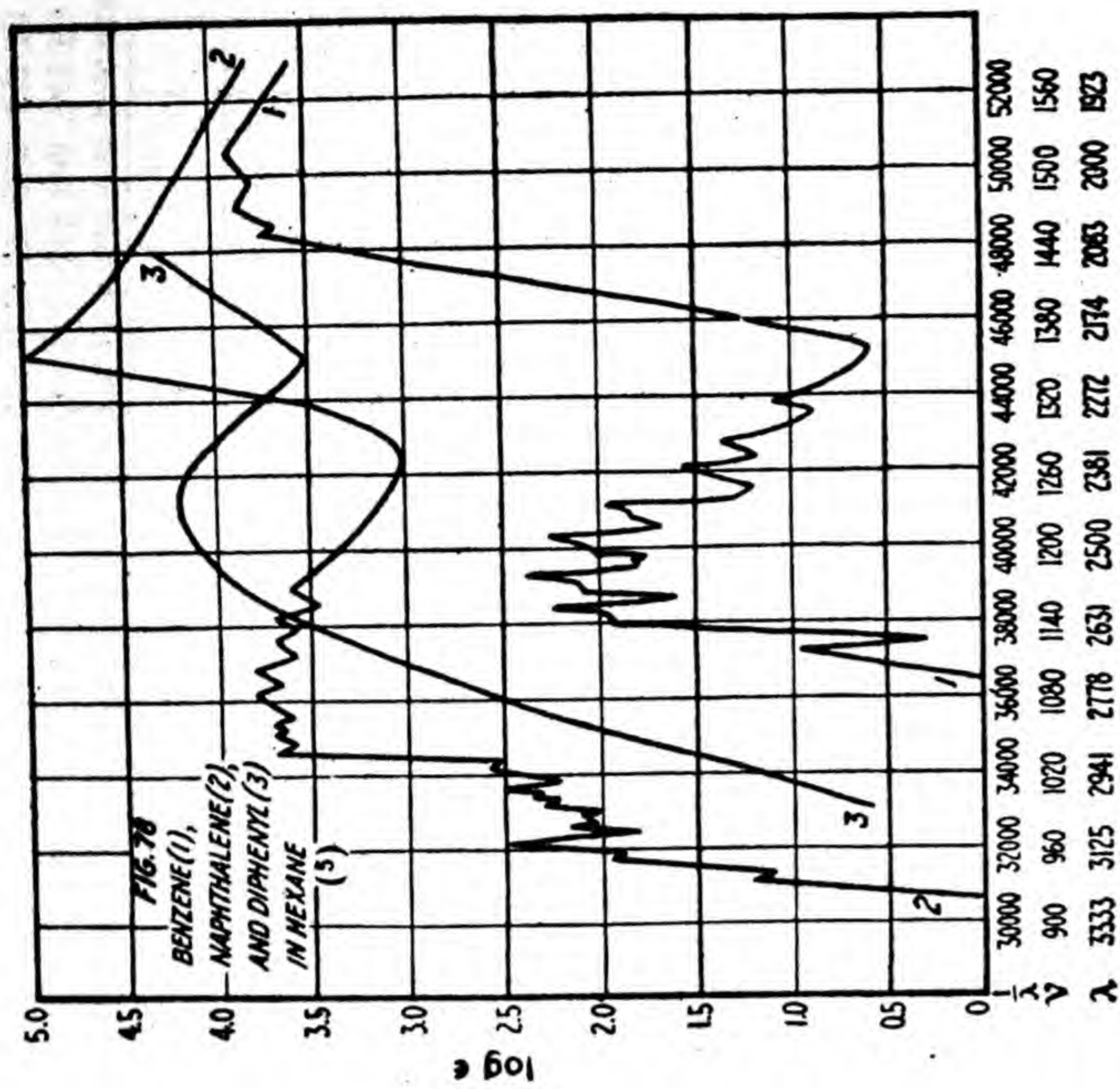




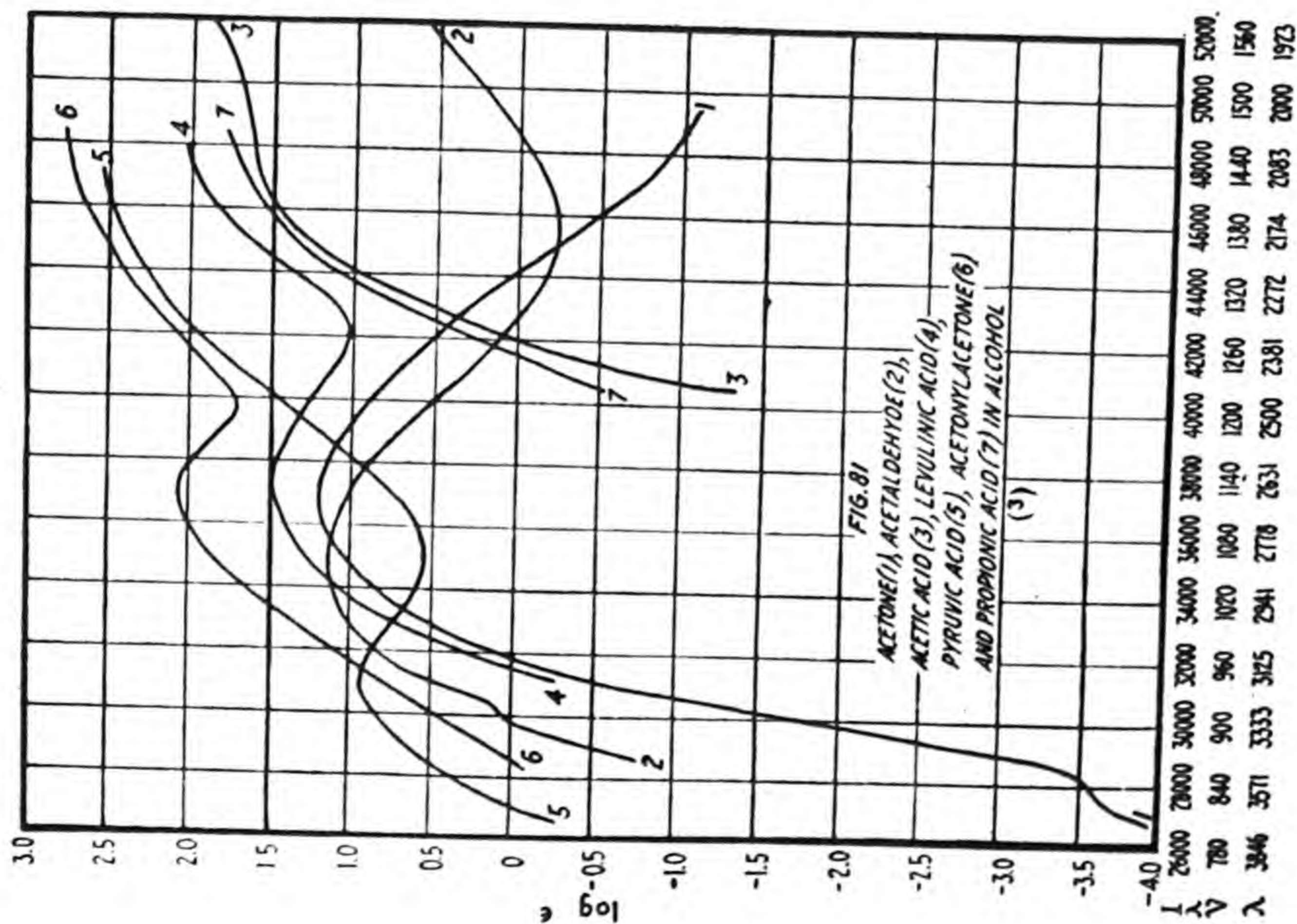
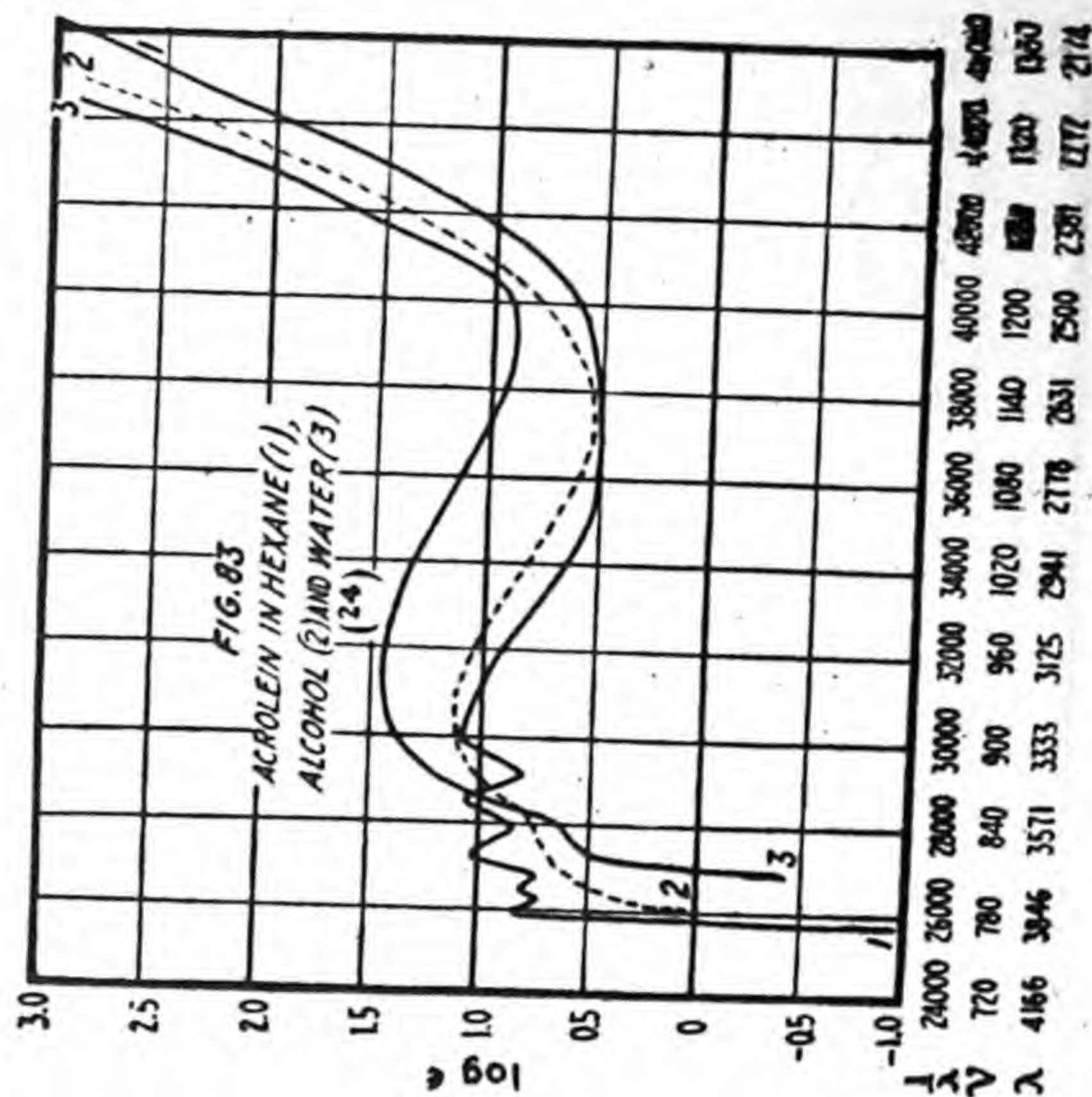
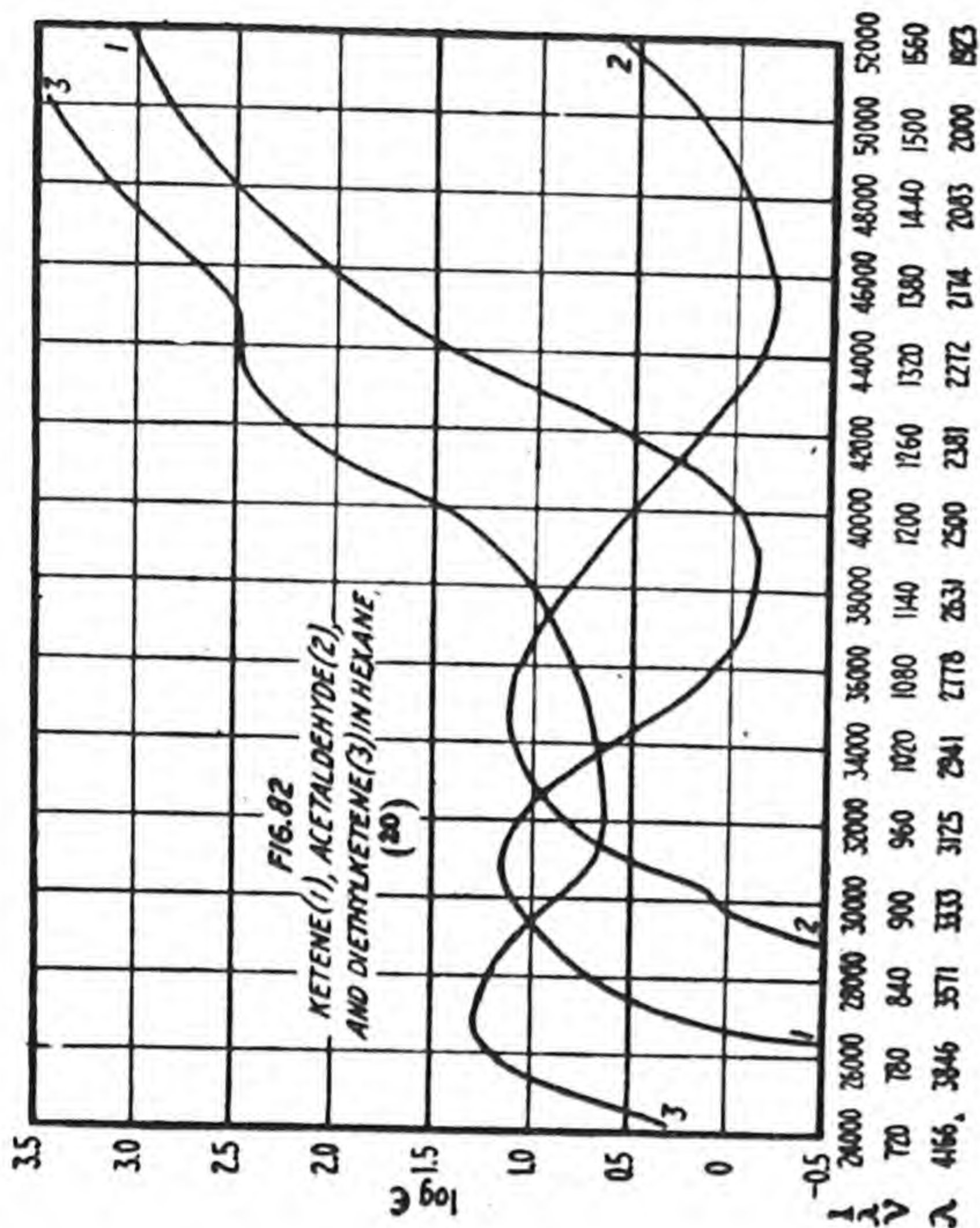




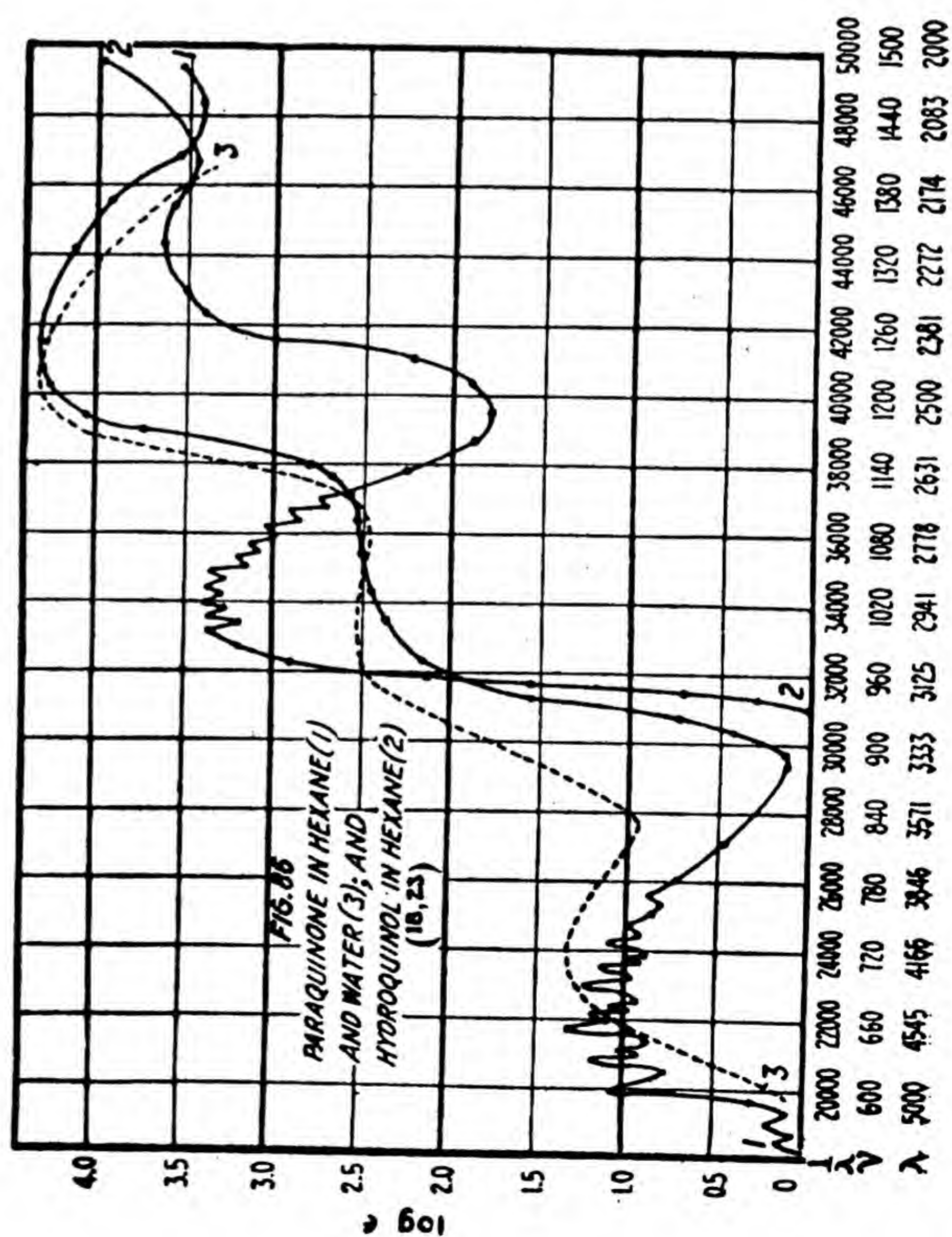
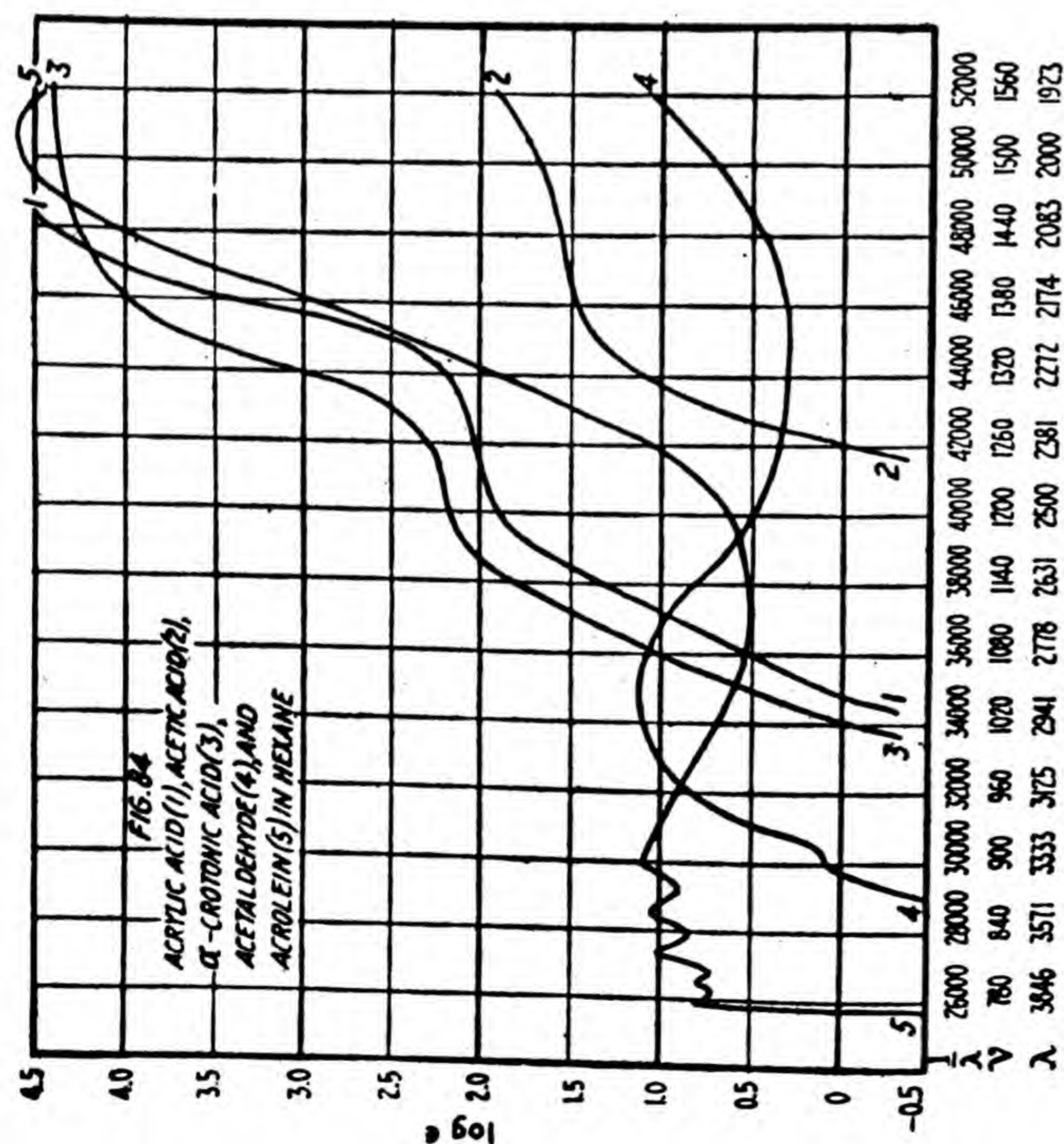
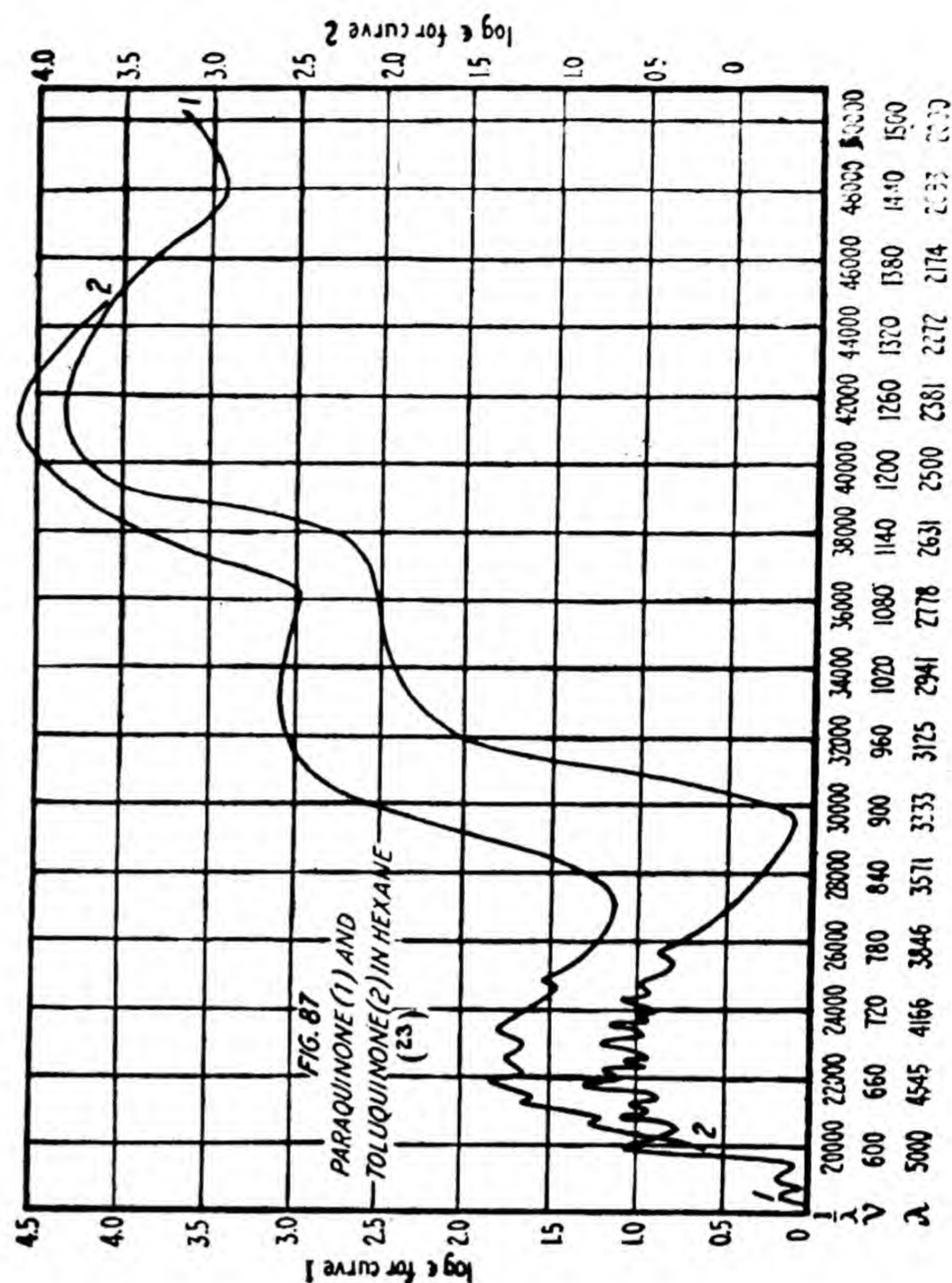
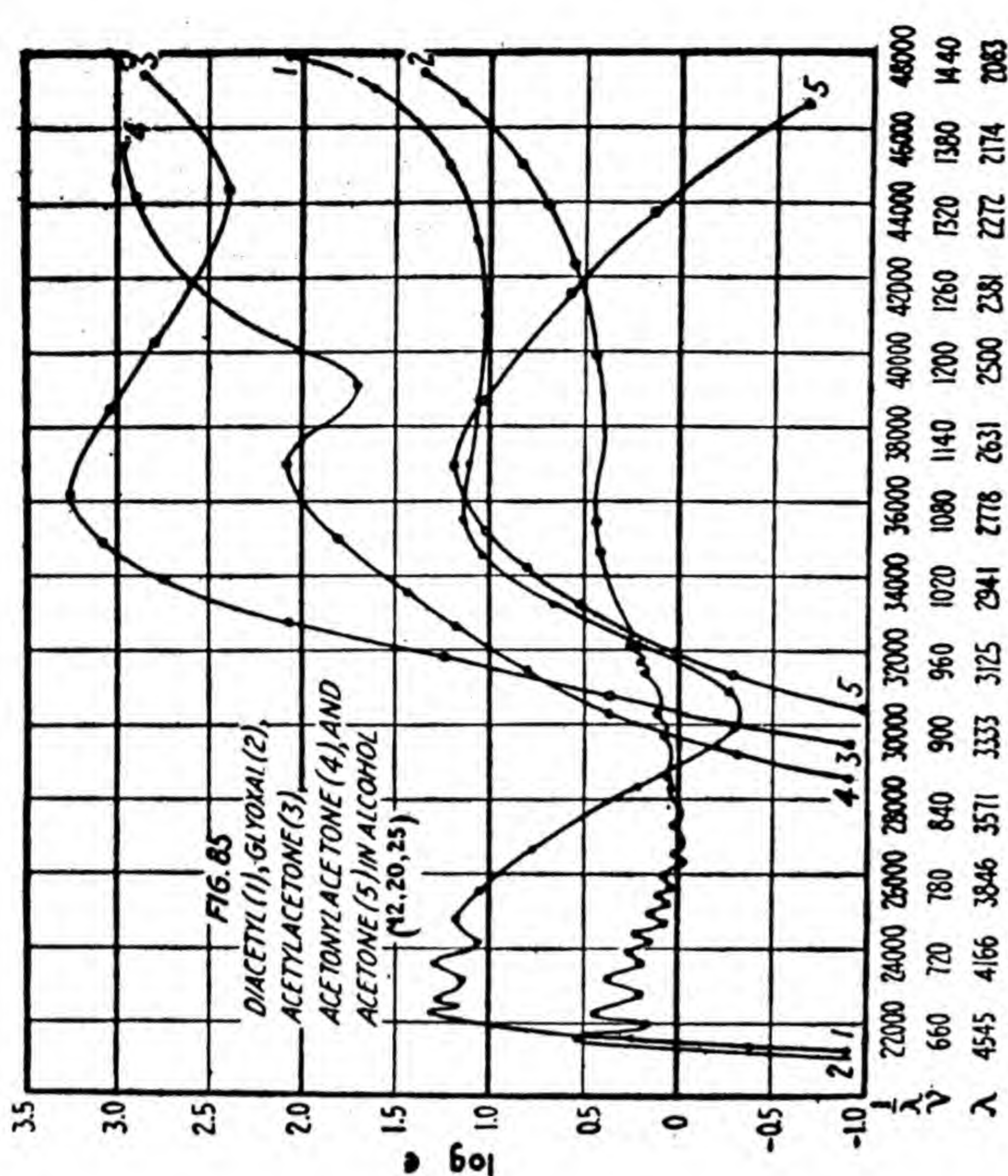




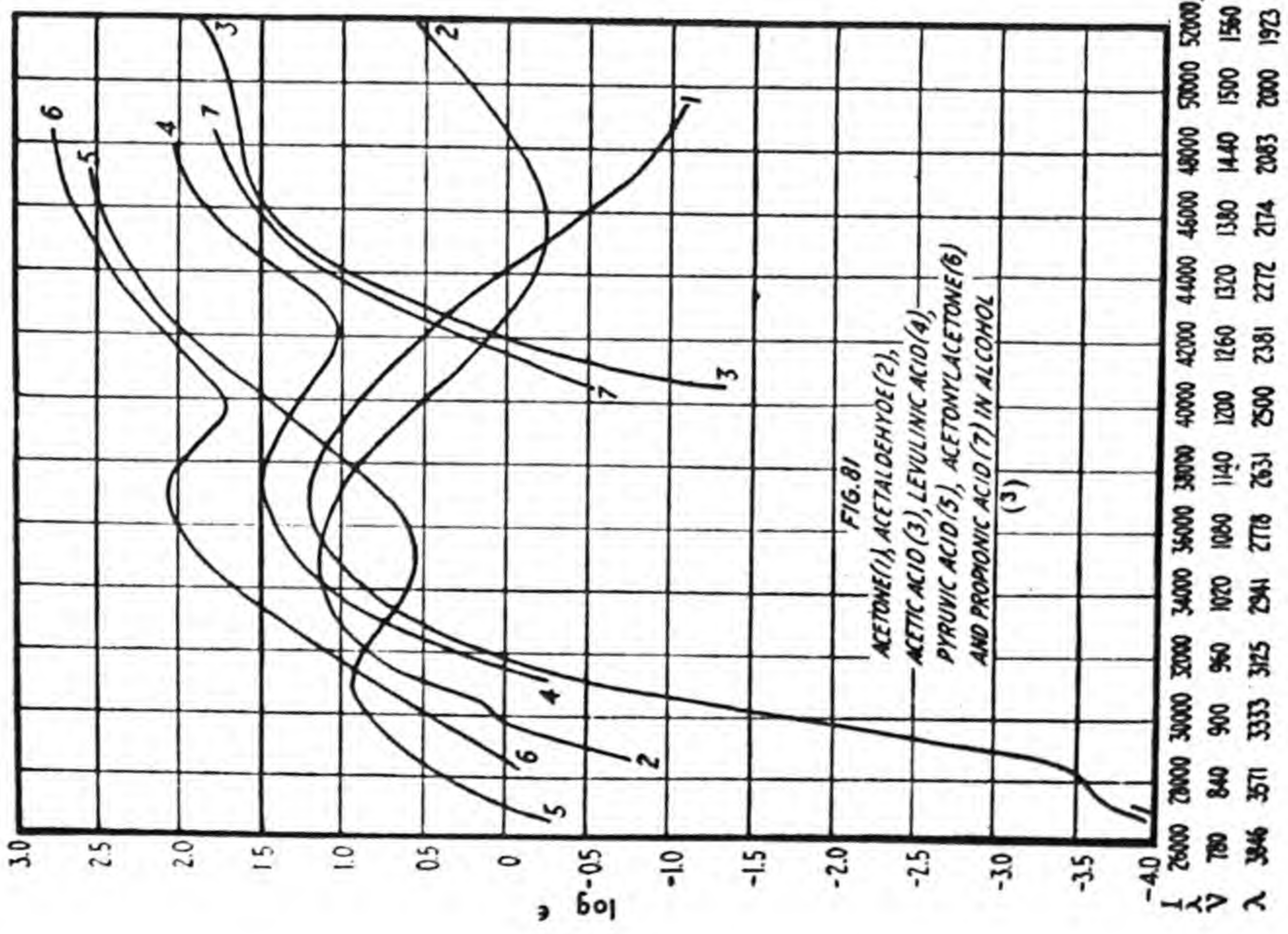
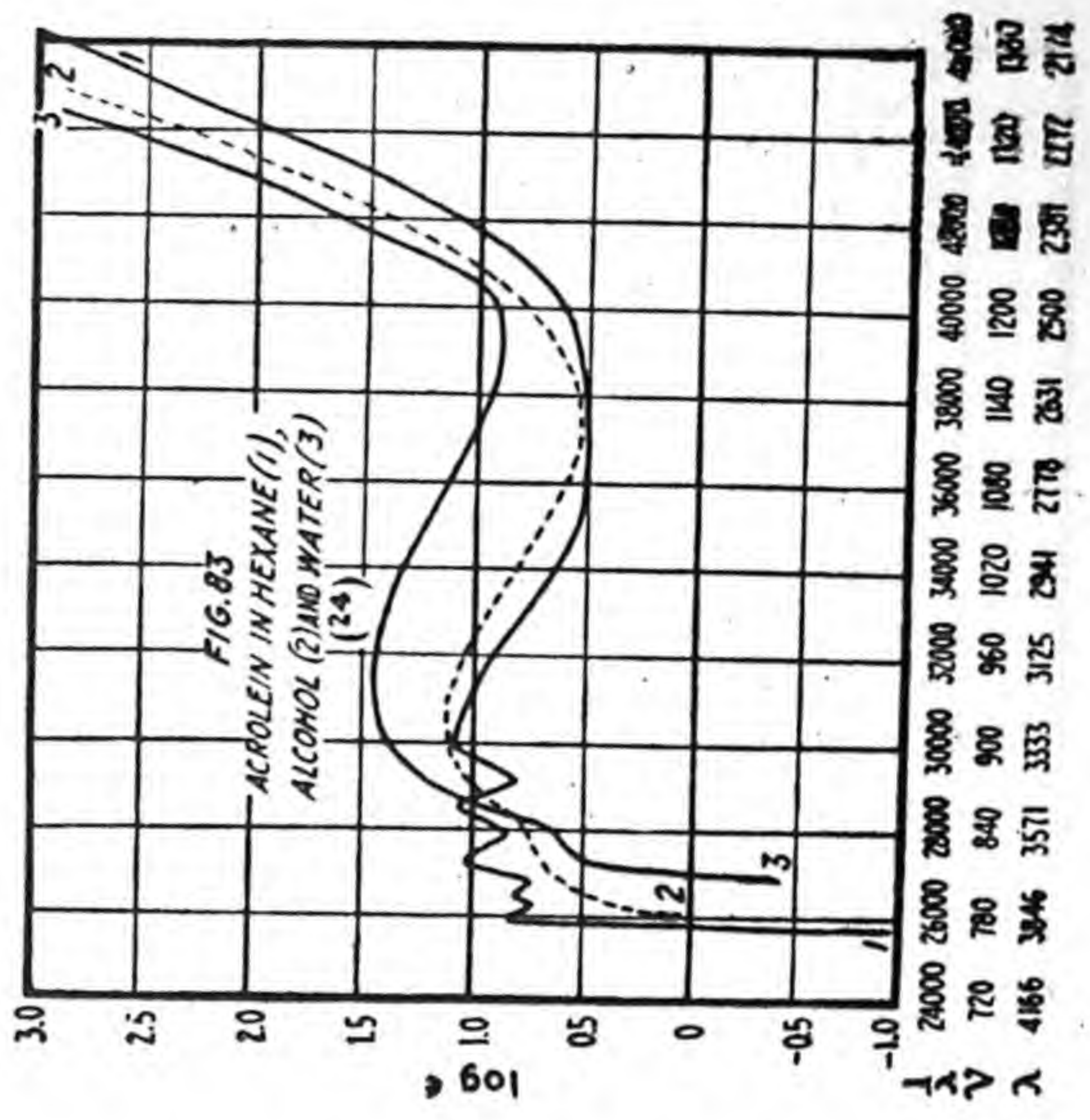
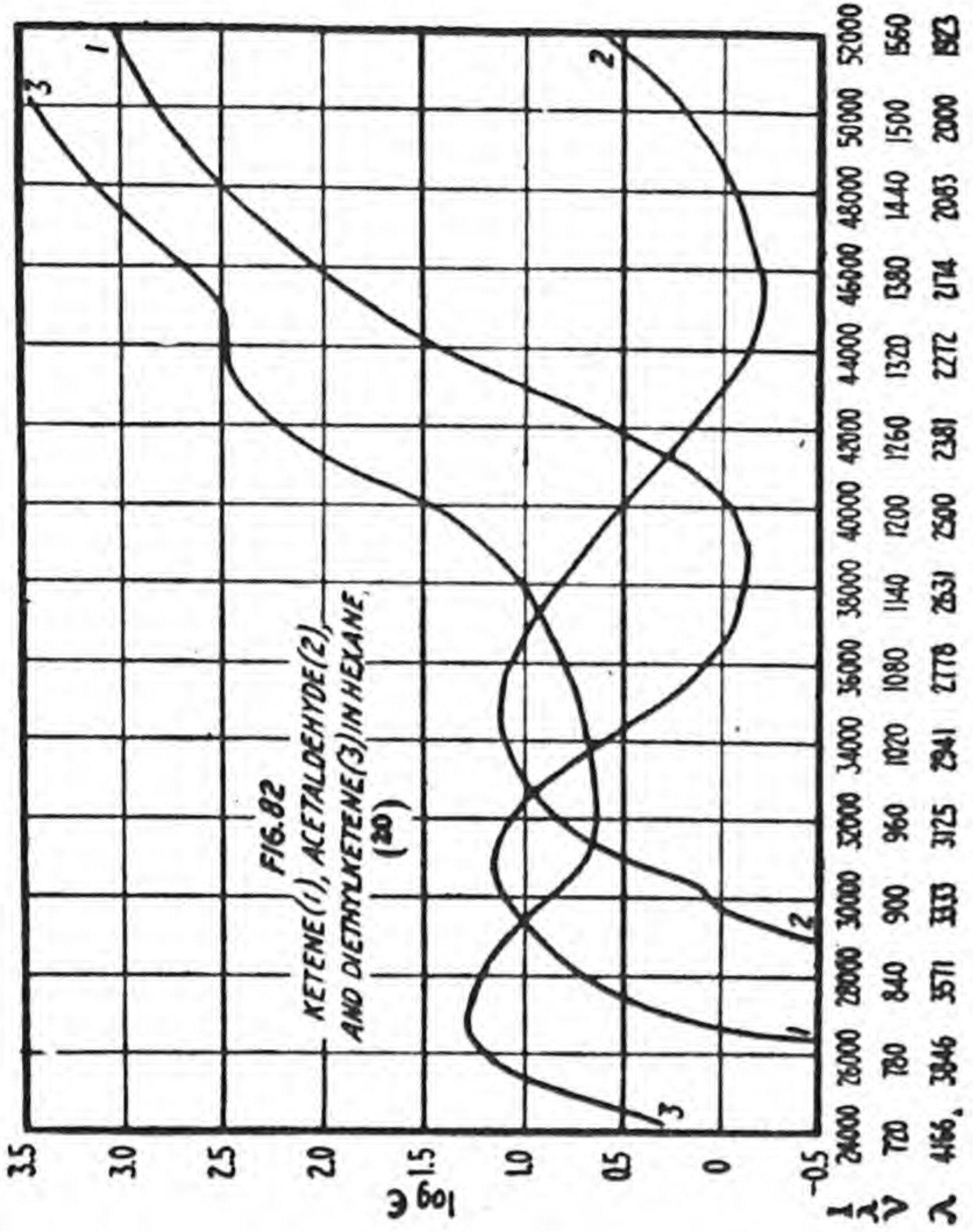




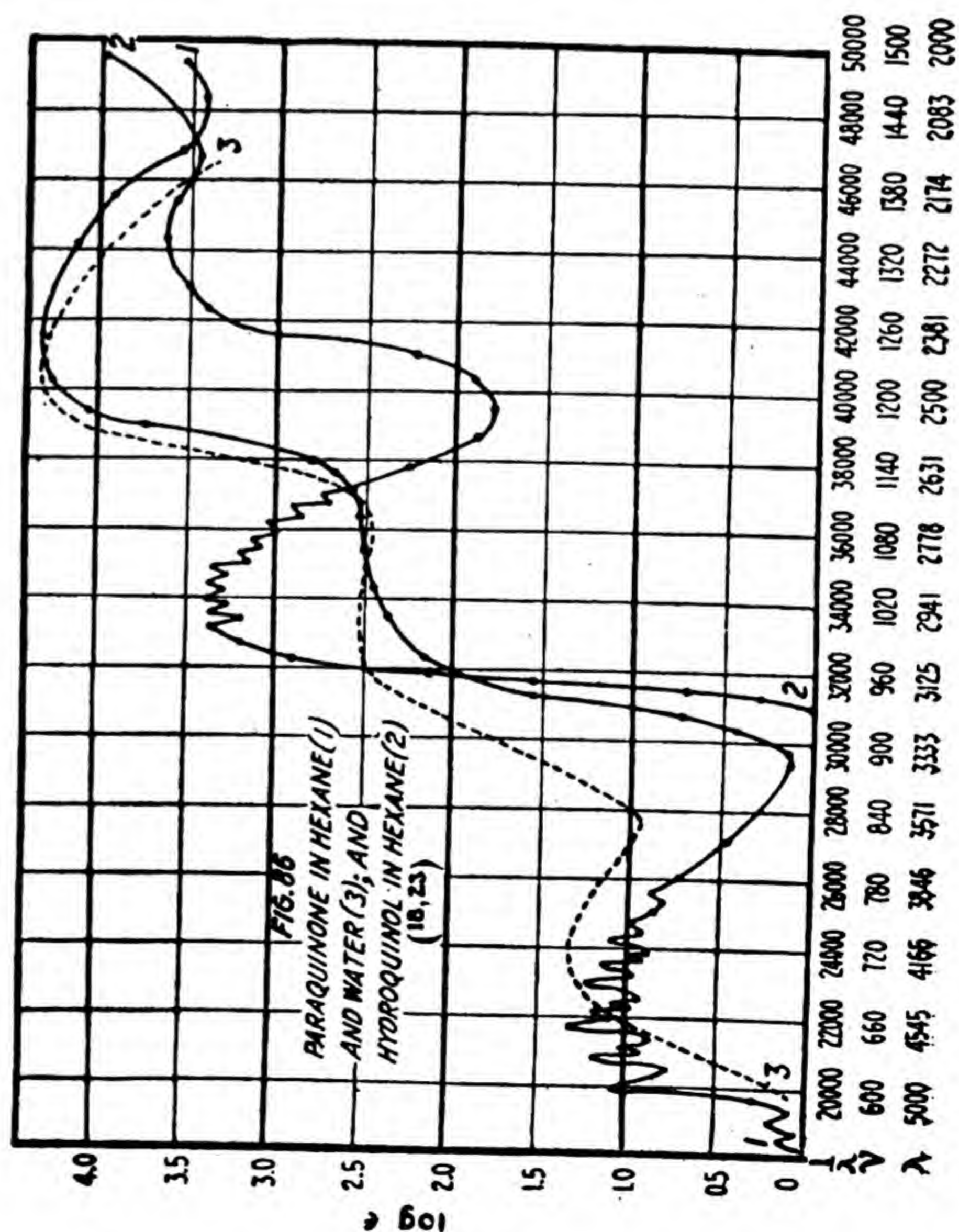
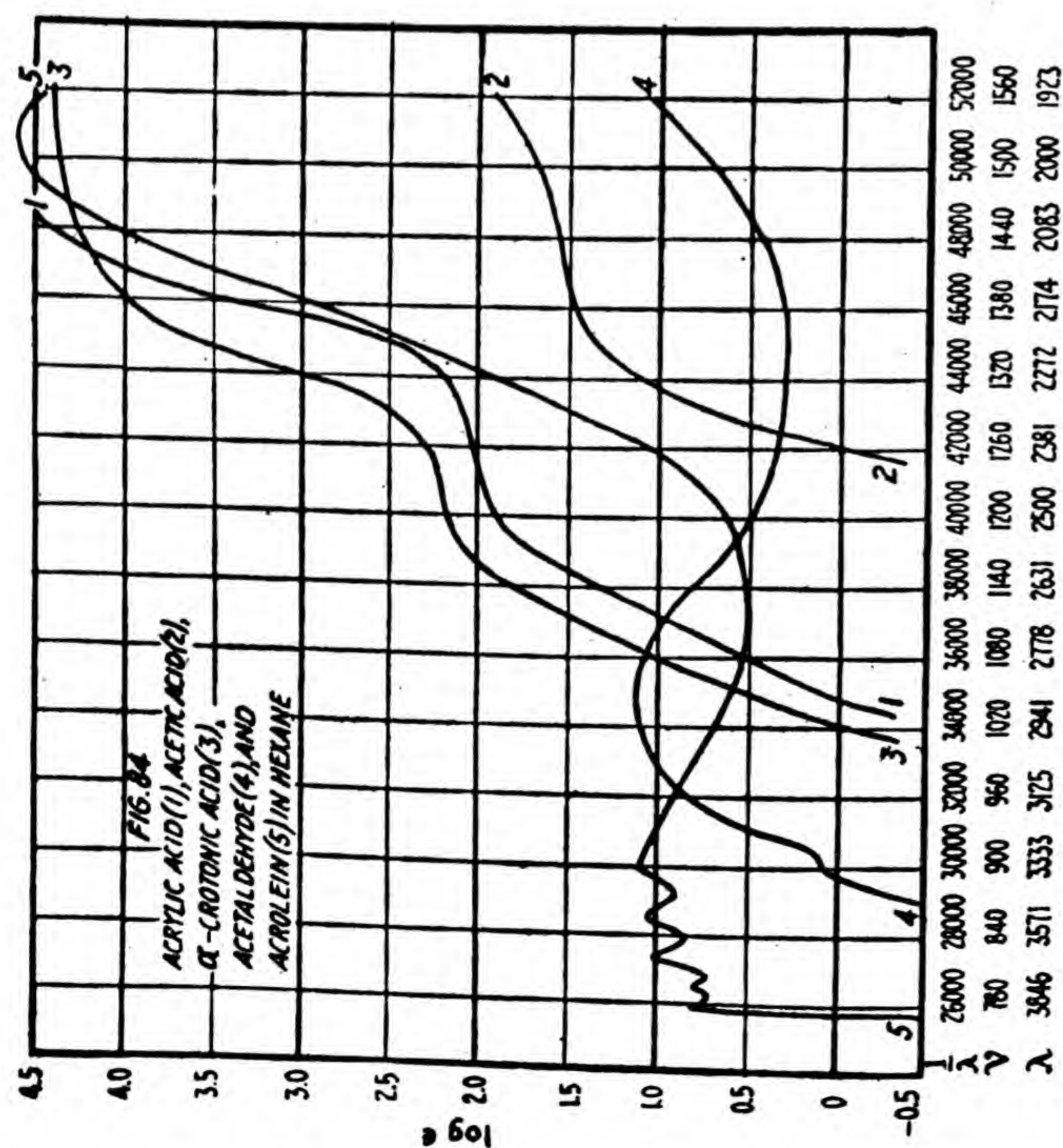
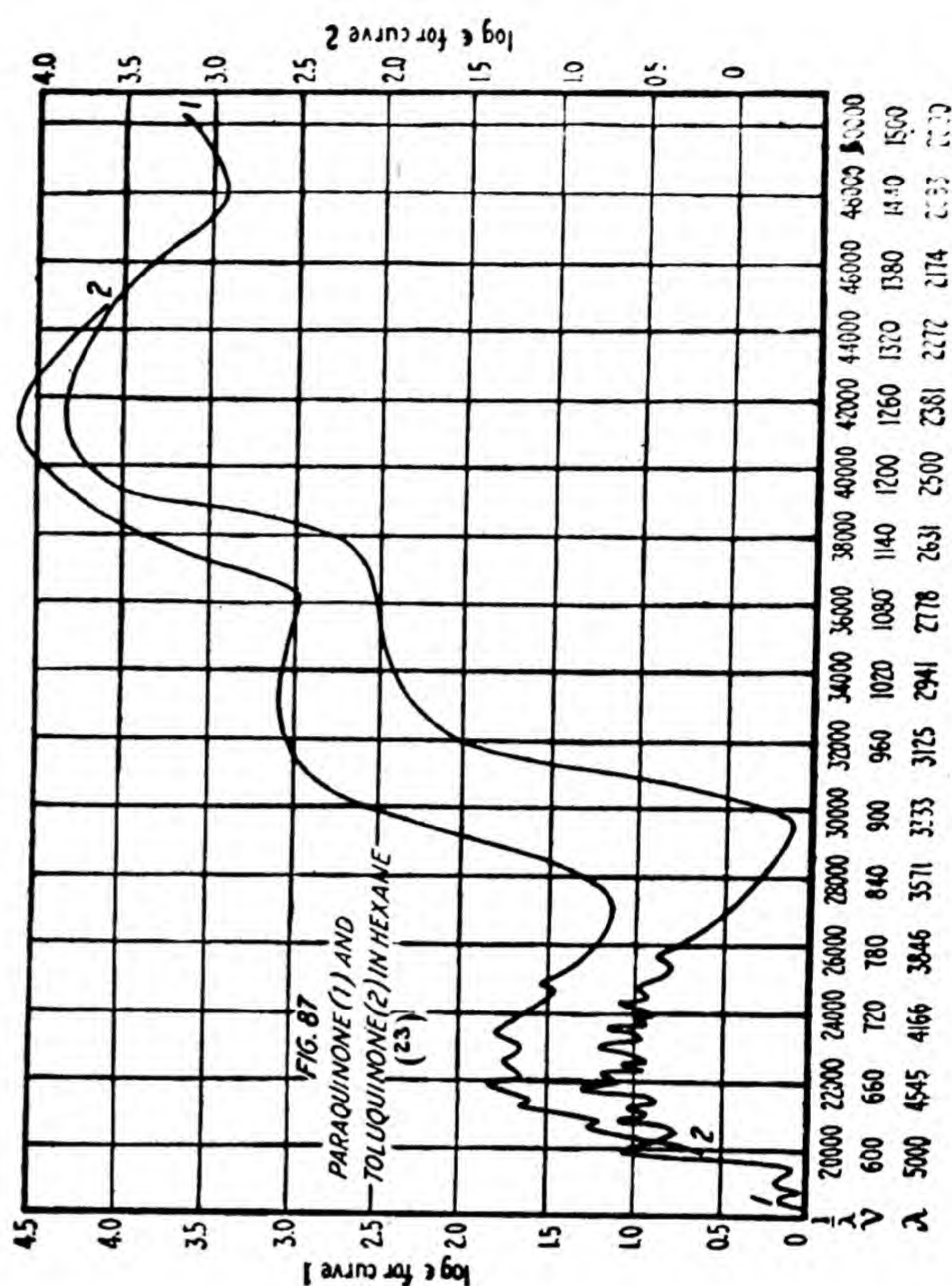
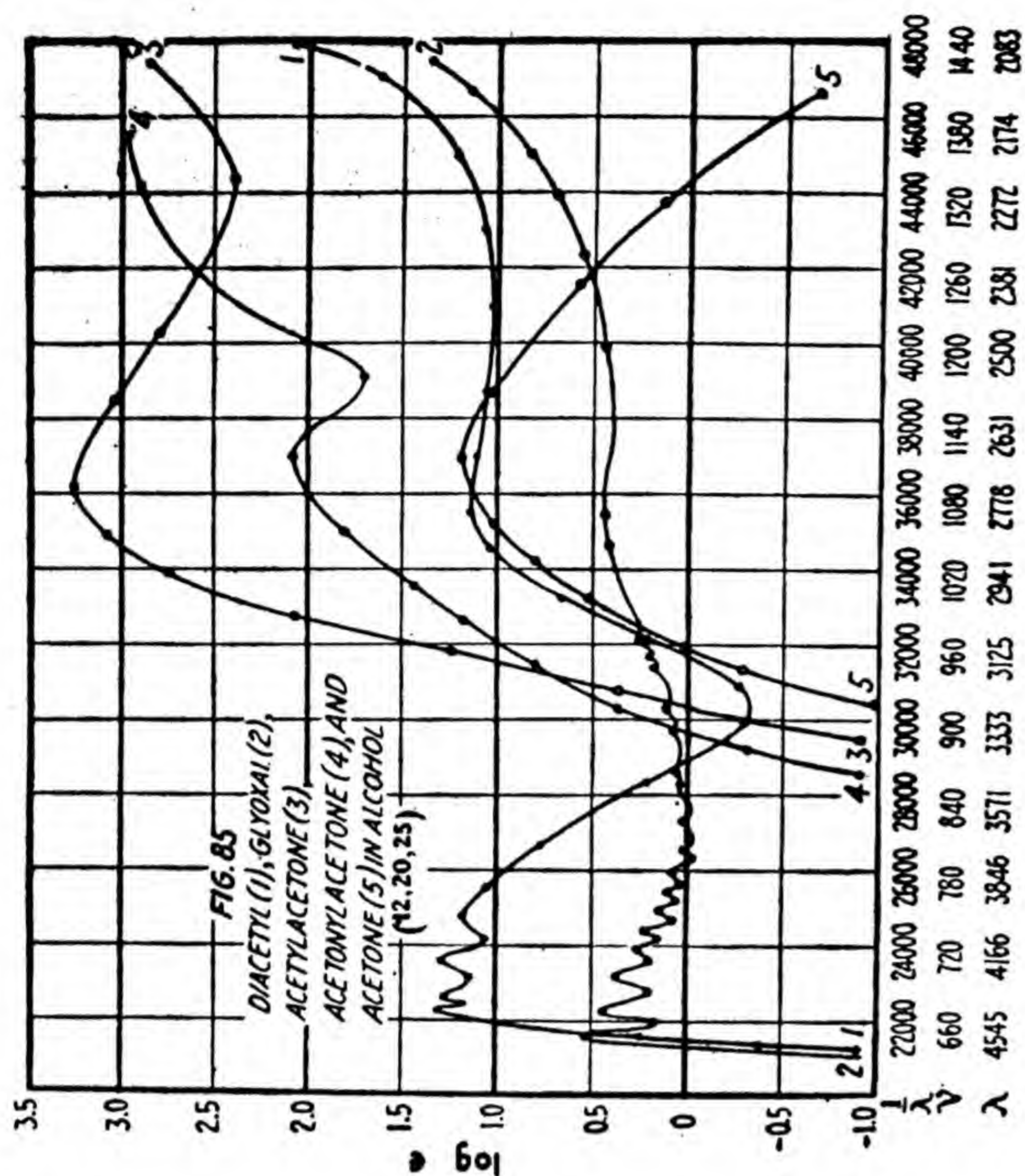




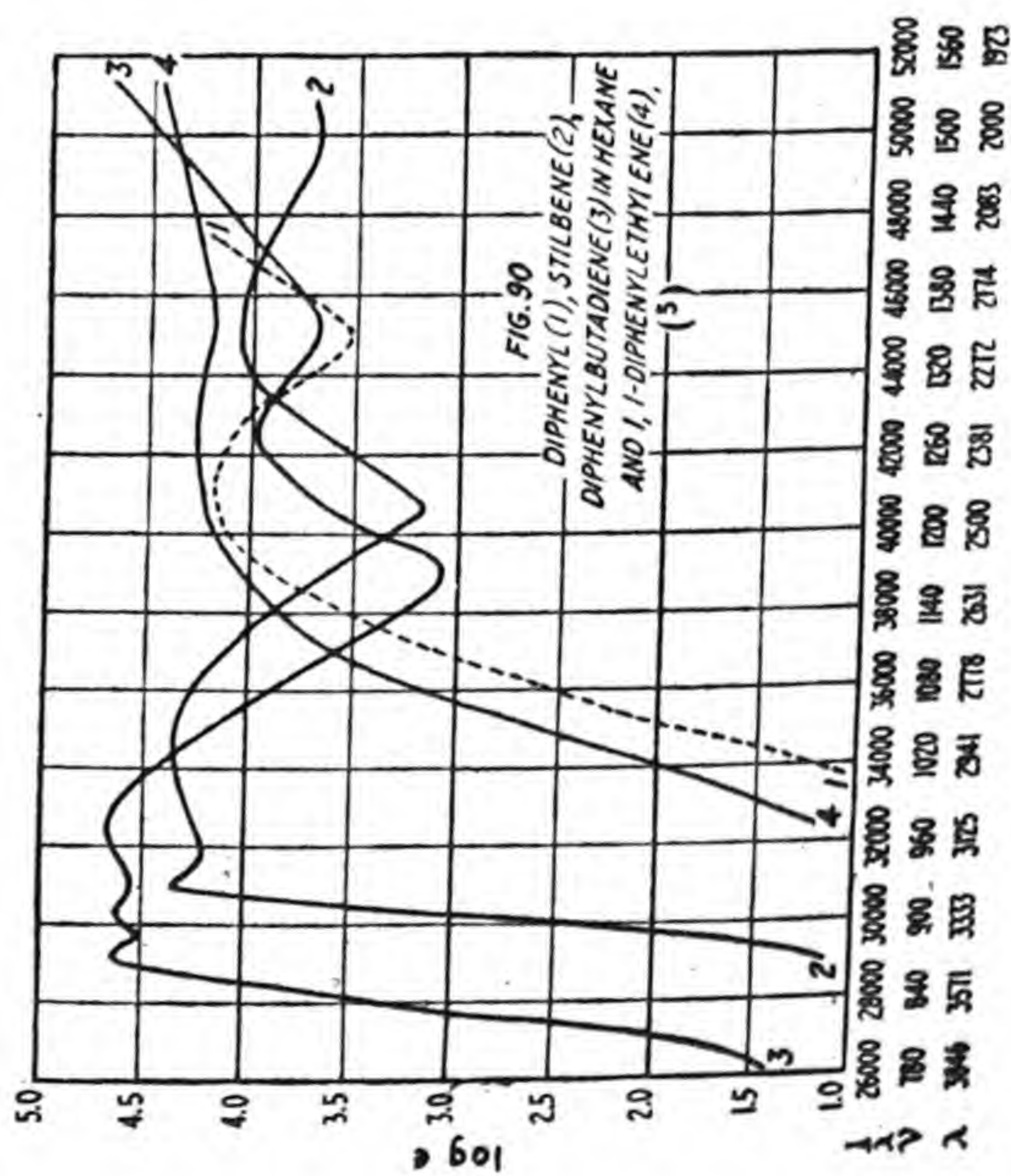
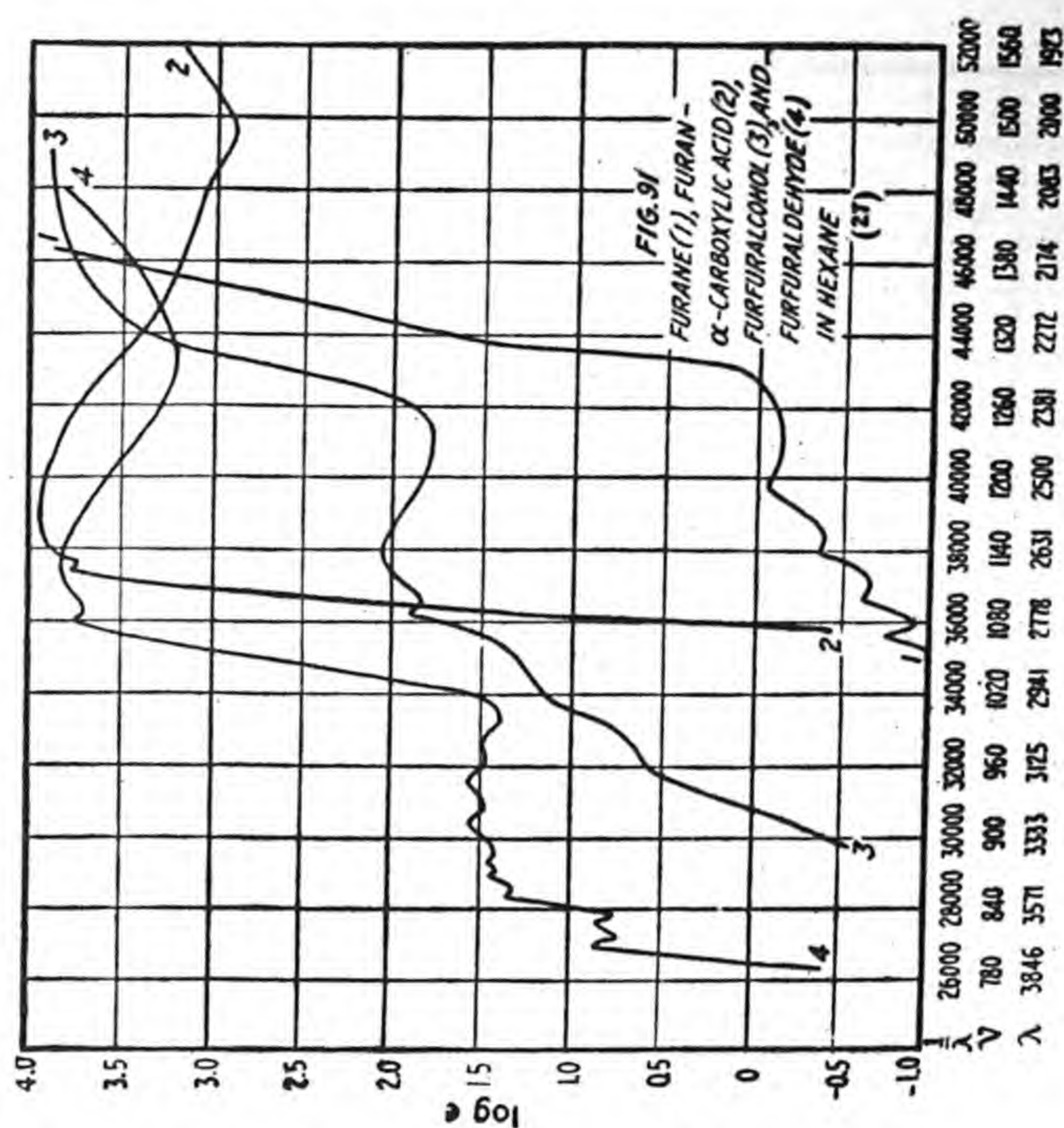
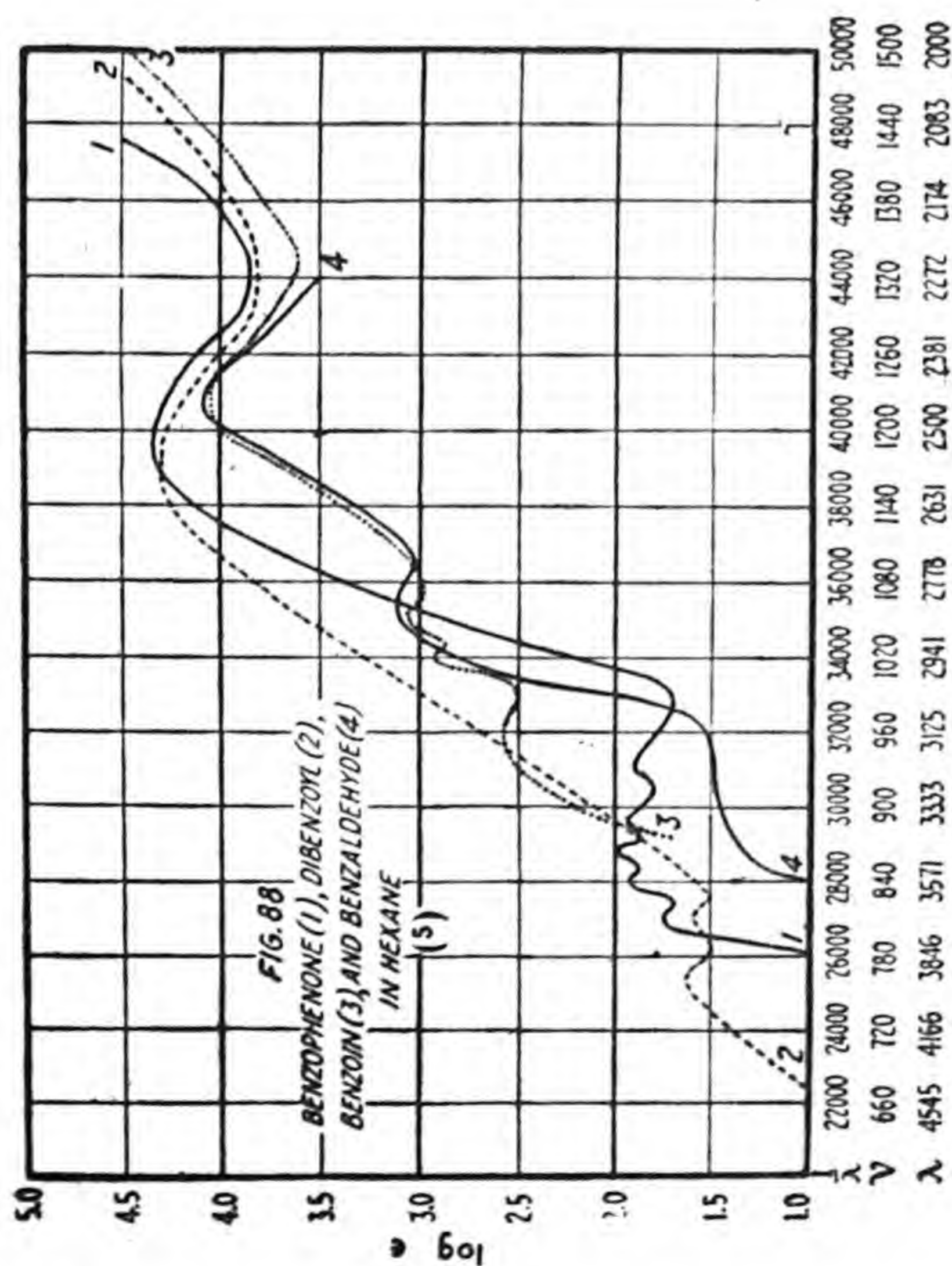
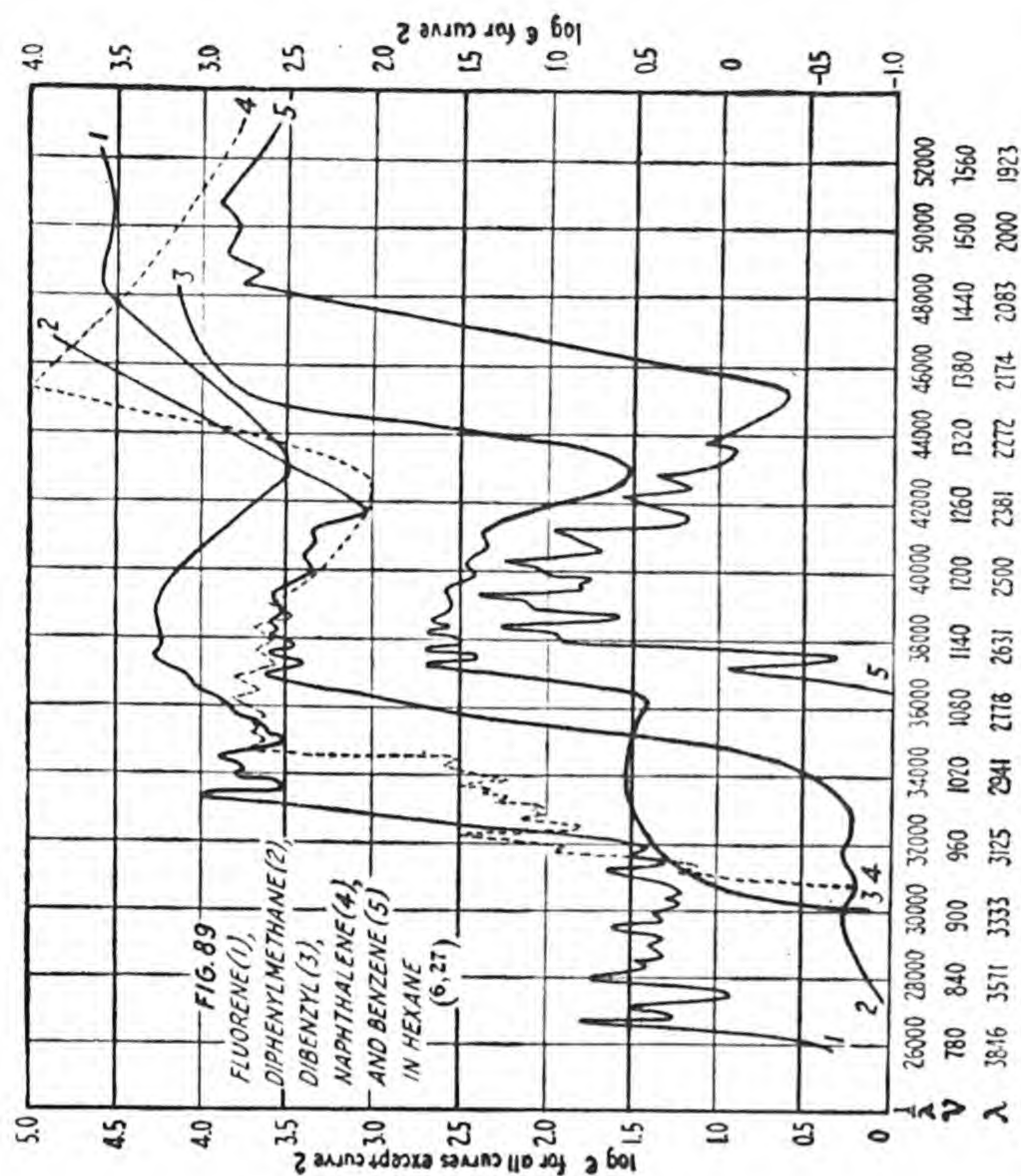




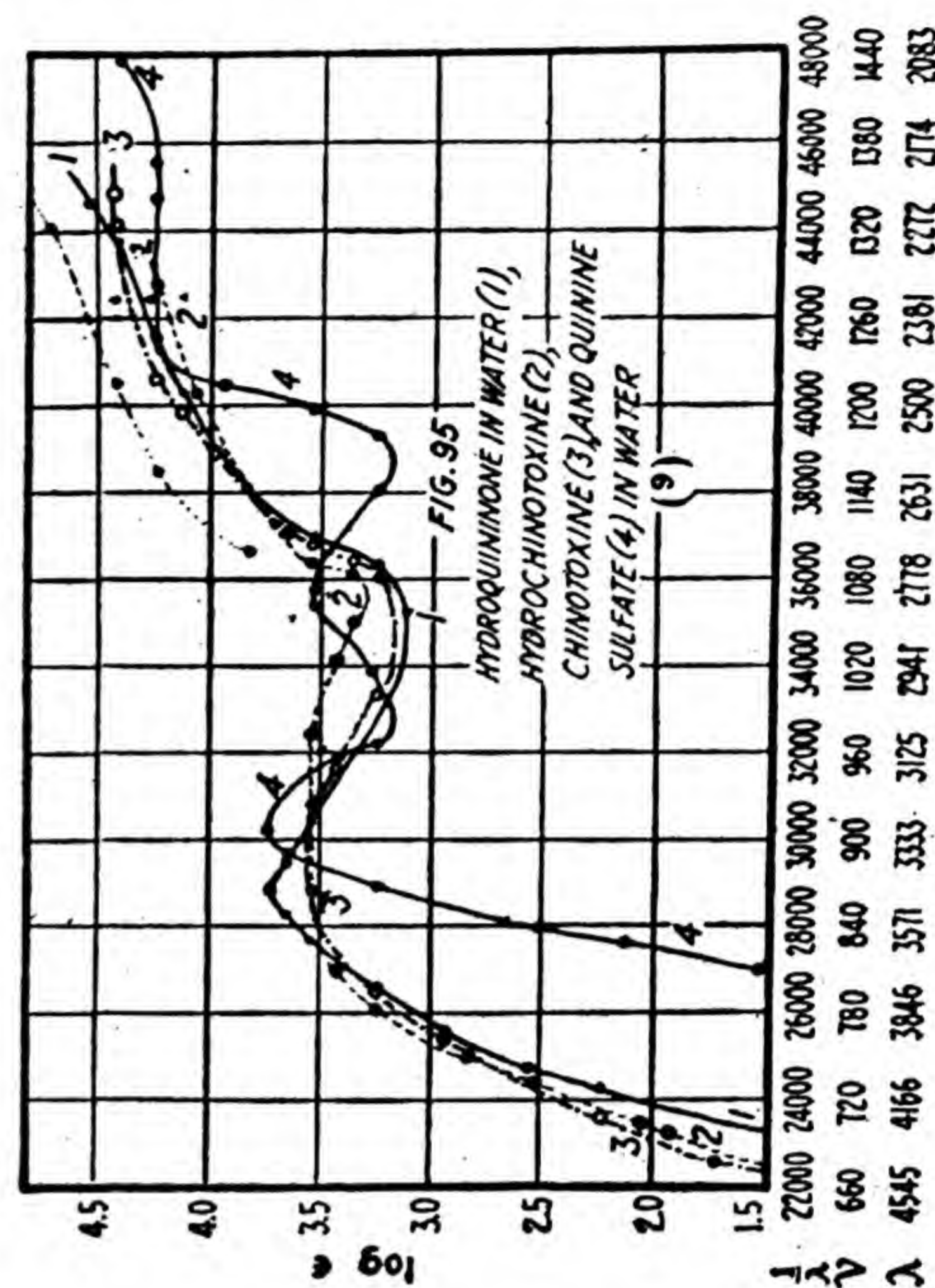
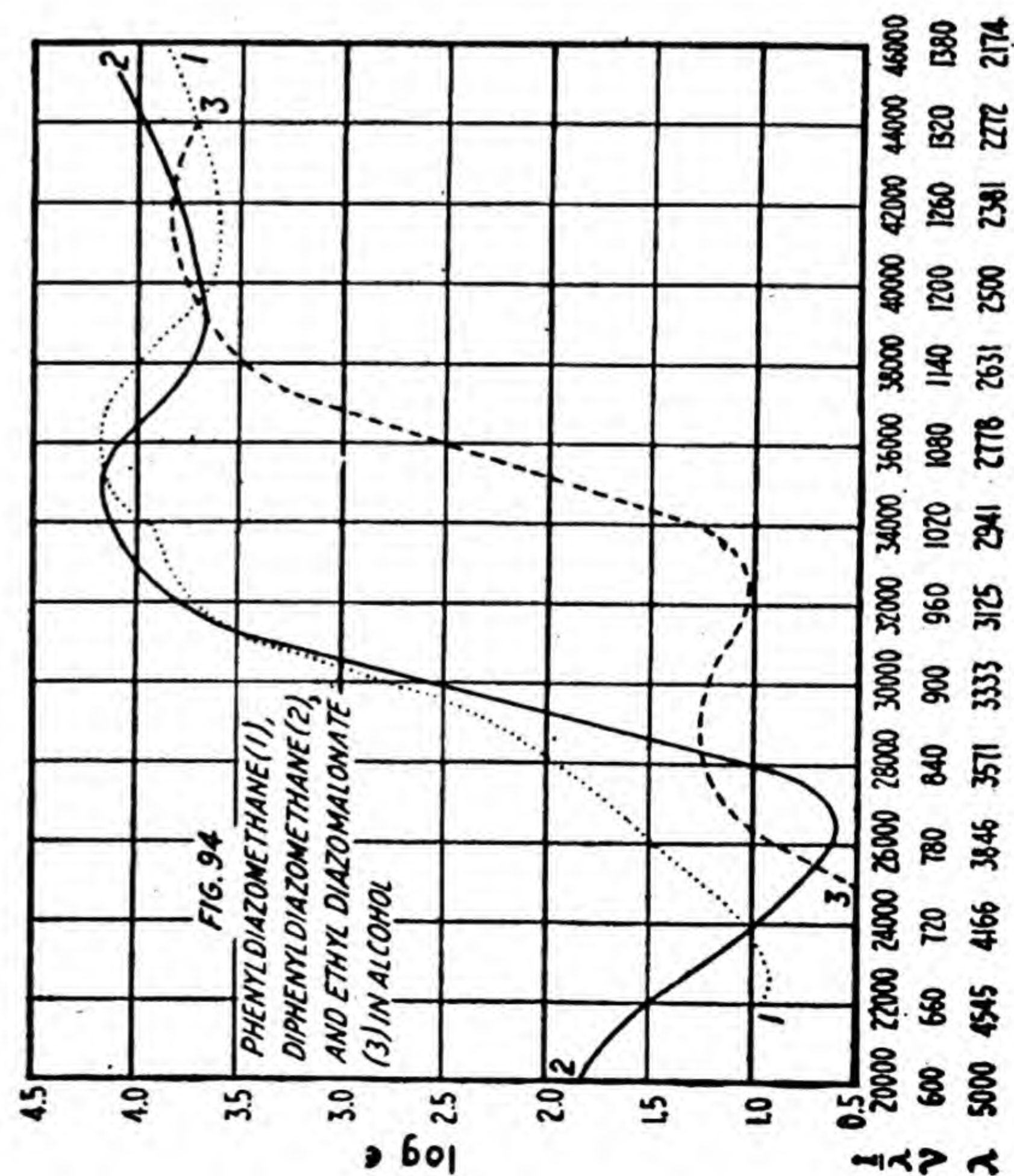
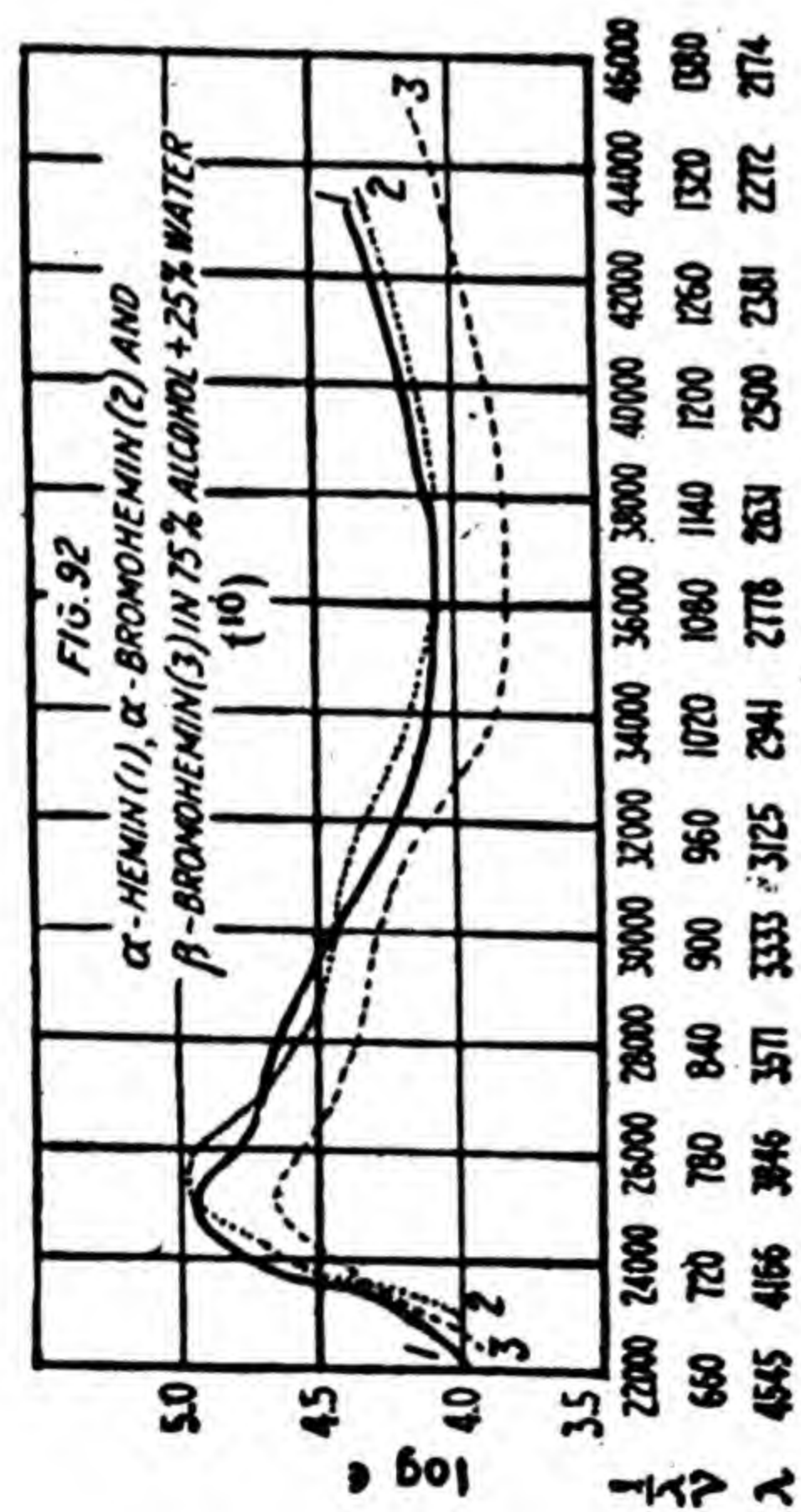
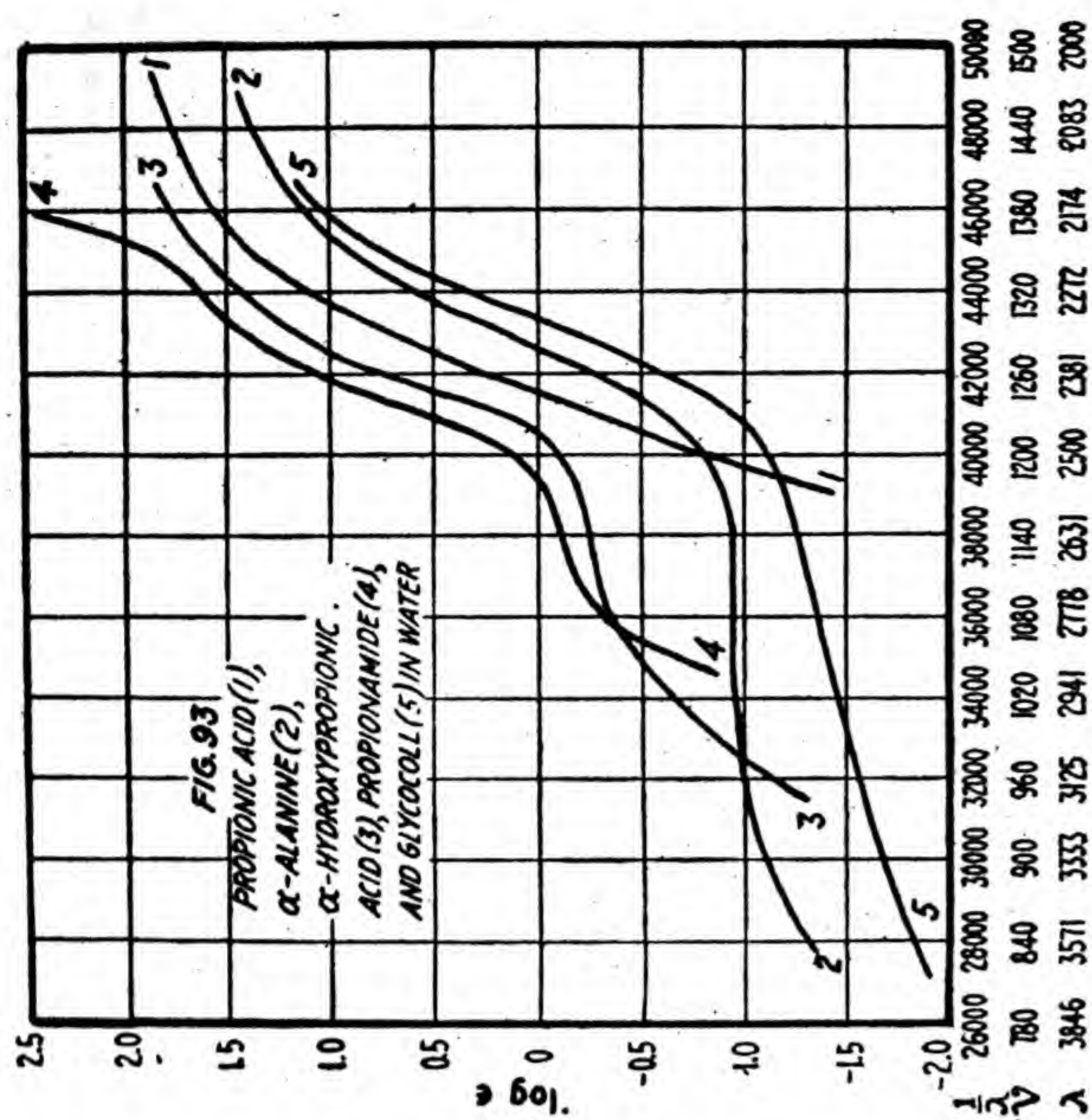














## SOLAR SPECTRUM

HAROLD D. BABCOCK AND W. S. ADAMS

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TABLE 1.—SOLAR SPECTRUM: TYPICAL LINES

An *R* placed after a wave-length ( $\lambda$ ) indicates that it has been derived from Rowland's measurements (4) by means of Table 2; all other values of  $\lambda$  are derived from measurements made at Mount Wilson (3) in terms of internationally accepted standards. They all represent the value of  $\lambda$  in air at 15°C and a pressure of one normal atmosphere. Accidental errors exceeding 0.002 Å or 0.003 Å are improbable. The source of the line is generally that determined by Rowland. The spot intensities refer to typical spots; in "Spot  $\delta\lambda$ " are given the separations of the *n*-components in large spots, reduced to a common field strength ( $H = 3400$  gauss). A line which is incompletely resolved from other nearby details of the spectrum *blends* with them, and is called a *blend*. Unit of  $\lambda = 1$  Int. Å =  $10^{-4}$  μ =  $10^{-8}$  cm; of  $\delta\lambda = 10^{-3}$  Å =  $10^{-11}$  cm.

$\lambda$	Source (4)	Intensity		Spot $\delta\lambda$ (3)	Group (1, 3, 5)	Temp. class (2)
		Sun (4)	Spot (3)			
3741.067	Ti	4				
48.273	Fe	10			a1	IA
52.417	Fe	3			e(?)	
56.943	Fe	4				IV
58.247	Fe	15			b1	II
60.538	Fe	4			b	III
69.996	Fe	4				IV
81.193	Fe	3				IV
90.659		1				
3804.016	Fe	3				IV, —
10.762	Fe, C	3				
21.188	Fe	4			d	IV
33.319	Fe	4				IV
42.057	Co	3				II
50.828	Fe	4			b	II
63.404	C	3N				
73.769	Fe	4				IV
85.521	Fe	4			b	III
91.936	Fe	4			d	V
3906.492	Fe	10		11	a1	I
06.756	Fe	4		12	d(?)	V
16.739	Fe	5	5	10	b	IV
20.271	Fe	10	8	12	a1	I
24.535	Ti	4	4	9	a1	II
37.339	Fe	3	3	14	b	IV
49.963	Fe	5	5	10	b	III
60.288	Fe	4	3	7		
71.334	Fe	5	5	8	b	III
77.752	Fe	6	5	14	b4	III
95.992	Fe	3	3	5	b	IV
4007.281	Fe	3	2	6	b	IV
20.907	Co	3	3	10		I
29.647	Fe-Zr	5	4	14		
40.649	Fe	3	3	8	e	

TABLE 1.—(Continued)

$\lambda$	Source (4)	Intensity		Spot $\delta\lambda$ (3)	Group (1, 3, 5)	Temp. class (2)
		Sun (4)	Spot (3)			
4053.273	Fe	2	2	12		
62.451	Fe	5	5	10	b	III
70.778	Fe	4	3	11		III
71.751	Fe	15	15	7	b1	II
95.983	Fe	3	3	8	d(?)	IV
4104.135*	Fe	5	5	17	d	V
14.453	Fe	4	4	10	b	IV
25.888	Fe	3	2	19		
36.530	Fe	4	4	4	d	
39.939	Fe	6	7	9	a	IIA
54.507	Fe	4	4	12	b	III
54.815	Fe	4	4	17	d	IV
67.279	Mg(?)	8	6	13		
75.645	Fe	5	5	9	b	III
84.902†	Fe, Cr	4	4	13	b	III, III
95.342	Fe	5	5	13	d	IV
4202.042	Fe	8	9	10	b1	I
07.135	Fe	3	3	10	b	IV
08.612	Fe	3	3	10	d(?)	V
20.349	Fe	3	3	9	b	IV
22.223	Fe	5	6	11	d	III
33.613	Fe	6	8	10	d5	III
46.838	Sc+	5	4	8		IVA
57.663	Mn	2	3	15		II
65.268	Fe	2	2	13		
79.492	Fe	2	2	6		
* 82.413	Fe	5	6	14	b1	III
83.016	Ca	4	7	8		I
91.475	Fe	2	3	19	a3	IA
4302.540	Ca	4	7	12		I
18.660	Ca, Mn(?)	4	6	16		I, —
26.764	Fe	2	2	11		
27.112	Fe	3	2	16	b	V
37.056	Fe	5	7	9	b3	II
38.273	Fe	1	1	9	b	
51.556	Fe	2	2	13	b	IV
52.745	Fe	4	6	18	b3	III
65.906	Fe	2	2	10		
69.781	Fe	4	4	19	b3	III
73.570	Fe	2	2	13		
75.946	Fe	6	10	14	a3	I
83.559	Fe	15	15	13	b1	II
88.416	Fe	3	3	22	d(?)	IV
4404.763	Fe	10	10	14	b1	II
15.137	Fe	8	8	15	b1	II
16.829	Fe+	2	0	11		
25.446	Ca	4	6	7		I
27.319	Fe	5	9	16	a3	I
35.158	Fe	2	4	14	a	IIA
43.203	Fe	3	3	9	b3	III
54.390	Fe	3	4	13	b3	III
61.662	Fe	4	7	14	a3	IB
69.385	Fe	4	4	19	d	IV



TABLE 1.—(Continued)

$\lambda$	Source (4)	Intensity		Spot $\delta\lambda$ (3)	Group (1, 3, 5)	Temp. class (2)
		Sun (4)	Spot (3)			
4481.618*	Fe	1	1	35		
84.229	Fe	4	4	17	<i>d</i>	IV
85.685	Fe	3	3	36	<i>e</i> (?)	IV
94.575	Fe	6	8	15	<i>c4</i>	III
4502.225	Mn	2	2	28		III
12.745	Ti	3	6	25	<i>a1</i>	II
17.536	Fe	3	3	36		
34.788	Ti	4	6	18	<i>a1</i>	II
47.856	Fe	3	4	18		
63.767	Ti+	4	3	17		VE
71.104	Mg	5	8	19		
78.562	Ca	3	7	10		II
89.955	Ti+	3	2	23		
4602.951	Fe	6	8	22	<i>b</i>	IB(?)
07.655	Fe	4	4	14	<i>d</i>	V
17.280	Ti	3	5	20	<i>a1</i>	II
25.054	Fe	5	6	41	<i>d</i>	IV
30.130	Fe	4	4	26		
38.019	Fe	4	4	31	<i>d</i> (?)	IV
47.445	Fe	4	6	21	<i>b</i>	IV
78.857	Fe	6	6	22		V
4704.956†	Fe	4	4	99		
22.165	Zn	3	1	60		
33.598	Fe	4	6	18	<i>b</i>	IB(?)
41.537	Fe	3	3	27	<i>b</i>	V
72.824	Fe	4	5	23	<i>b</i>	III
89.660	Fe	3	3	25	<i>b</i>	V
4802.888	Fe	2	1	31		
10.539	Zn	3	1	36		
24.143	Fe, Cr+	3	2	48		
32.721	Fe	3	2	25		
40.886	Ti	3	6	20	<i>a1</i>	I
48.254	Cr+	2	00	26		
59.749	Fe	4	6		<i>c5</i>	III
66.278	Ni	2	1	46		III
85.436	Fe	3	2	21	<i>d</i>	V
4904.420		3	2			
09.390	Fe	2	2	44		
17.237	Fe	2	2	60		
24.778	Fe	3	4	31	<i>b</i>	V
27.874	Fe	2	1	46		
30.313	Fe	2	2	31		
37.350	Ni(?)	3	1	55		III
38.179	Fe	2	2	15	<i>d</i>	
39.244	Fe	2	2	32	<i>d</i> (?)	
46.397	Fe	3	3	43	<i>d</i>	IV
67.905	Fe	3	2		<i>e</i>	
69.924	Fe	3	2			
94.139	Fe	3	6	27	<i>a</i>	IB
98.232	Ni	1	00	56		III
5005.720	Fe	4	4	35	<i>d</i>	V
10.944	Ni	0	0	46		
20.033	Ti	2	6	30	<i>a1</i>	II
24.852	Ti	3	7	17	<i>a1</i>	II
25.568*	Ti	1	3	34		III
28.135	Fe	2	2	24		V
39.966	Ti	3	5	22	<i>a1</i>	I
49.829	Fe	6	8	28	<i>a</i>	III
60.076	Fe	3	6	37	<i>a</i>	
74.755	Fe	5	4	33	<i>e</i>	V
81.121	Ni	3	3	31		III

TABLE 1.—(Continued)

$\lambda$	Source (4)	Intensity		Spot $\delta\lambda$ (3)	Group (1, 3, 5)	Temp. class (2)
		Sun (4)	Spot (3)			
5082.351	Ni	2	0	40		
99.938	Ni	2	2	50		V
5110.409	Fe	5	9		<i>a</i>	IB
23.732	Fe	3	3		<i>a</i>	IB
31.478§	Fe	2	1	126	<i>a</i>	
41.748	Fe	3	5	34		
50.854	Fe	4	7		<i>a</i>	IB
59.065	Fe	2	2	42		
71.612	Fe	6	8		<i>a</i>	II
85.910	Ti	2	1	38		
91.467	Fe	4	5		<i>d</i>	IV
94.951	Fe	4	7		<i>a</i>	IB
97.578	Fe+	2	1	28		
5210.394	Ti	3	6	40	<i>a1</i>	I
25.535	Fe	2	3	131	<i>a</i>	IA
29.862	Fe	4	4	51	<i>d</i>	V
42.501	Fe	2	2	38	<i>a</i>	
50.218	Fe	2	2	182	<i>a</i>	IA
50.656	Fe	3	4	60	<i>b</i>	IV
63.316	Fe	4	4	65	<i>d</i>	V
73.172	Fe	3	3	54	<i>d</i>	
81.800	Fe	5	8	47	<i>d</i>	
88.533	Fe	2	2	44		
97.387	Cr	2	4	45		II
5302.308	Fe	5	6	57	<i>d</i>	V
07.370	Fe	3	5	46	<i>a</i>	III(?)
22.051	Fe	3	3	28	<i>b</i> (?)	
29.149	Cr	3	5	75		II
36.795	Ti+, -	4	3	58		VE,
45.809	Cr	5	10	44		I
49.471	Ca	4	6	40		III
64.883	Fe	5	5	30	<i>e</i>	V
67.478	Fe	6	7	39	<i>e</i>	V
69.976	Fe	6	6	40	<i>e</i>	V
83.381	Fe	6	6	42	<i>e</i>	V
89.488	Fe	3	3	54		
93.178	Fe	5	6	63	<i>d5</i>	IV
97.143	Fe	7	14	49	<i>a4</i>	IB
5410.920	Fe	4	4	42	<i>e</i>	V
15.211	Fe-V	5	5	43	<i>e</i>	V, -
24.081	Fe	6	6	46	<i>e</i>	V
34.536	Fe	5	8	10	<i>a4</i>	IB
36.304	Fe	1	1	84	<i>b</i> (?)	
45.055	Fe	4	4	49	<i>e</i>	V
62.971	Fe	3	3	40	<i>e</i>	
66.407	Fe	3	3	50	<i>d</i>	
73.911	Fe	3	3	65	<i>d</i>	
80.867	Fe	1	1	96	<i>d</i>	
87.756	Fe	3	4	58		
97.528¶	Fe	5	13	222	<i>a3</i>	IB
5501.478	Fe	5	12	144	<i>a3</i>	IB
06.793**	Fe	5	12	146	<i>a3</i>	IB
12.991	Ca	4	8	40		III
34.849		2	1	27		
54.902	Fe	3	2	75	<i>e</i>	
62.718	Fe	2	2	96		
76.101	Fe	4	4	0	<i>d5</i>	IV
81.981	Ca	4	8	54		III
88.766	Ca	6	10	39		III
90.128	Ca	3	7	49		III
93.748	Ni	0	00	46		III



TABLE 1.—(Continued)

$\lambda$	Source (4)	Intensity		Spot $\delta\lambda$ (3)	Group (1, 3, 5)	Temp. class (2)
		Sun (4)	Spot (3)			
5601.288	Ca	3	6	52		III
14.784	Ni	0	00	60		V
18.645	Fe	1	1	81	<i>d</i>	
24.033	Fe	1	1	48	<i>d5</i>	
33.955	Fe	3	3	53	<i>d</i>	
38.274	Fe	3	3	52	<i>d5</i>	V
41.450	Fe	2	2	52	<i>d</i>	
50.696	Fe	1	0	78		
55.502	Fe	2	2	58	<i>d</i>	V
62.527	Fe	4	3	51	<i>d</i>	V
67.526	Fe	2	2	110	<i>e</i> (?)	
79.034	Fe	3	3	84	<i>e</i> (?)	
82.650	Na	5	10	40		
84.497	Si	3	1	60		
88.220	Na	6	12	43		
90.435	Si	3	1	86		
5701.113	Si	1	00	98		
01.559	Fe	4	5	50	<i>e</i> (?)	III(?)
08.408	Si	3N	00	73		
11.098	Mg	6	6	43		
17.844	Fe	4	4	41	<i>d</i>	
31.775	Fe	4	3	101	<i>d</i>	
52.043	Fe	4	4	79	<i>e</i> (?)	
54.669	Ni	5	6	77		II
63.005	Fe	6	6	55	<i>d</i>	V
72.152	Si	3	0	53		
75.091	Fe	4	4	94	<i>d</i>	
87.930	Cr	4	9	63		III
93.926	Fe	2	2	104	<i>d</i> (?)	
5806.736	Fe	5	5	58	<i>e</i> (?)	
09.228	Fe	4	4	70	<i>d</i>	
16.384	Fe	5	5	44		
48.126	Fe	3	2	88	<i>d</i>	
52.232	Fe	3	4	80		
53.690	Ba+	5	9	72		III
62.371	Fe	6	6	59	<i>e</i>	V
66.464	Ti	3	10	49	<i>a1</i>	II
89.977	Na	30	100			I
92.885	Ni	4	4	50		II
95.943	Na	20	60			I
5905.684	Fe	4	3	34	<i>d</i>	V
16.261††	Fe	3	5	80		
27.801	Fe	2	2	28	<i>e</i> (?)	
34.669	Fe	5	5	57	<i>d</i>	V
48.552	Si	6	2	54		
56.709	Fe	4	10	32	<i>b</i>	
75.356	Fe	3	3	46	<i>b4</i>	
83.693	Fe	5	5	62	<i>d</i>	V
84.830	Fe	6	6	62	<i>e</i>	IV
6003.027	Fe	6	6	98	<i>d</i>	V
07.973	Fe	4	4	89	<i>e</i>	
13.503	Mn	6	11	155		III
16.653	Mn	6	12	192		III
21.808	Mn	6	12	106		III
27.064	Fe	4	4	64	<i>b4</i>	V
39.745R	V	0	6	135		I
42.108	Fe	3	2	38	<i>e</i>	V
56.018	Fe	5	5	50	<i>e</i>	V
58.177R	V	000N	3	330		IIA
		<i>d</i> (?)				
65.499	Fe	7	8	28	<i>b4</i>	III

TABLE 1.—(Continued)

$\lambda$	Source (4)	Intensity		Spot $\delta\lambda$ (3)	Group (1, 3, 5)	Temp. class (2)
		Sun (4)	Spot (3)			
6078.504	Fe	5	5	81	<i>e</i>	V
81.458R	V	0	7	145		I
82.723	Fe	1	1	173	<i>b</i> (?)	
90.222	Ti, V	2	8	59		—, I
96.675	Fe	3	3	127	<i>d</i>	
6102.188	Fe	6	5	109	<i>e</i>	V
02.733	Ca	9	25	179		II
08.130	Ni	6	7	95		II
11.666R	V	0 <i>d</i> (?)	10	188		II
19.535R	V	1	8	121		I
22.231	Ca	10	30	48		II
27.918	Fe	3	3	51	<i>b</i>	
35.375R	V	00N	8	188		
36.631	Fe	8	10	35	<i>b4</i>	III
37.709	Fe	7	9	98	<i>b4</i>	III
50.156R	V	0N	12	154		I
		<i>d</i> (?)				
57.739	Fe	5	6	198	<i>b4</i>	V
61.302	Ca	4	9	124		III
62.185	Ca	15	35	166		II
66.446	Ca	5	9	79		III
73.348	Fe	5	4	236	<i>b4</i>	III
80.216	Fe	5	7	45	<i>b</i> (?)	
91.577	Fe	9	9	69	<i>b4</i>	II
99.195R	V	0	8	178		I
6200.327	Fe	6	8	124	<i>b4</i>	IV
13.443	Fe	6	6	237	<i>b4</i>	III
13.877R	V	000	5	149		I
19.294	Fe	6	8	160	<i>b4</i>	III
24.512R	V	000	5	146		I
32.655	Fe	3	4	275	<i>d</i>	V
42.853R	V	000	5	184		I
46.333	Fe	8	7	148	<i>d5</i>	V
51.846R	V	00	7	164		I
52.571	Fe	7	9	67	<i>b</i>	III
58.368R	V	000N	0	149		IIA
61.299R	V	0000	000	196		IIA
65.148	Fe	5	8	152	<i>b4</i>	III
68.878R	V	000N	4	176		IIA
70.237	Fe	3	3	31	<i>b</i>	
85.182R	V	00N	6	154		I
92.828R	V	000	4	187		I
96.513R	V	0000	4	160		I
97.808	Fe	3	8	69	<i>b4</i>	III
6301.517	Fe	7	1	148	<i>d5</i>	IV
14.676	Ni	4	5	115		II
15.822	Fe	1	2	108		
18.035††	Fe	6	8	40	<i>b4</i>	III
22.701	Fe	4	6	145	<i>b</i>	III
35.345††	Fe	6	10	61	<i>b4</i>	III
36.837††	Fe	7	7	204	<i>d5</i>	V
55.043	Fe	4	6	114	<i>b</i>	III
58.695	Fe	6	8	176	<i>a</i>	IA
80.756	Fe	4	3	33	<i>b</i>	V
93.620††	Fe	7	8	36	<i>b4</i>	III
6400.328	Fe	2	4	147	<i>d5</i>	III
08.033††	Fe	5	7	60	<i>d</i>	V
11.665	Fe	7	9	44	<i>d5</i>	IV
21.367	Fe	7	10	162	<i>b</i>	III
30.863	Fe	5	8	140	<i>b4</i>	III
39.090	Ca	8	12	33		II



TABLE 1.—(Continued)

$\lambda$	Source (4)	Intensity		Spot $\delta\lambda$ (3)	Group (1, 3, 5)	Temp. class (2)
		Sun (4)	Spot (3)			
6449.827	Ca	6	11	48		II
55.613	Ca	2	8	45		II
71.676	Ca	5	10	149		II
81.886	Fe	3	4	144	b	
93.796	Ca	6	12	48		II
95.001	Fe	8	9	86	b4	II
96.480	Fe	2	2	97	d	
96.916	Ba+	4	6	52		
99.663	Ca	4	8	71		II
6546.260	Fe-Ti	6	8	48	b4, a4	III, III
69.232	Fe	5	4	122		V
92.934	Fe	6	6	62	b4	III
93.892	Fe	4	5	84	b4	IV
6609.126	Fe	3	4		b	IV
43.648	Ni	5	5			I
63.455	Fe	3	4		b	IV
78.007	Fe	5	5		b4	III
6717.697	Ca	5	8			III
50.173	Fe	3	3		b	IV
67.793	Ni	4	4			I
6810.276	Fe	4	2			
28.612	Fe	2	2		d(?)	V
41.356	Fe	3	3		d(?)	V
43.672	Fe	3	2		d(?)	V
55.183	Fe	3	2		d(?)	V

TABLE 2.—CORRECTIONS FOR ROWLAND'S VALUES OF  $\lambda$ 

Rowland's value exceeds the International value (i.e., system of standards adopted in 1922) by an amount  $\Delta$  which varies with  $\lambda$ .  $\S\S$  Unit of  $\lambda = 100 \text{ \AA} = 10^{-6} \text{ cm}$ ; of  $\Delta = 0.001 \text{ \AA} = 10^{-11} \text{ cm}$ .

$\lambda$ .....	38	40	42	44	46	48	49	50	51	52	53	54
$\Delta$ .....	137	149	158	158	173	184	177	174	169	164	172	200
$\lambda$ .....	55	56	58	59	60	61	62	63	64	65	66	68
$\Delta$ .....	204	216	211	212	214	206	204	204	204	213	227	242

TABLE 3.—CORRECTIONS FOR 1928 INTERNATIONAL STANDARDS (7)

Each  $\lambda$  in Table 1 is too great by an amount  $C$  which varies with  $\lambda$ . Error in  $C$  is probably  $< 0.001 \text{ \AA}$ . Unit of  $\lambda = 100 \text{ \AA} = 10^{-6} \text{ cm}$ ; of  $C = 0.001 \text{ \AA} = 10^{-11} \text{ cm}$ .

$\lambda$ .....	37.5	39.5	40.5	41.5	42.5	43.5	45	46	47	49
$C$ .....	1.5	2.0	2.0	2.0	2.0	2.0	2.6	3.1	3.0	2.8
$\lambda$ .....	51	55	57	59	60	62	64	66	67	
$C$ .....	2.6	2.3	3.0	3.8	4.7	6.5	8.4	10.2	11.2	

\* Blend in spot.

\*\* Complex in spot.

† Fe predominant.

†† Probably blend in spot.

‡ Blend with complex line in spot.

‡‡ Components blended in spot.

§ Doubtful. || Complex in spot.

§§ See also (6).

¶ Line complex;  $\delta\lambda$  is for outer  $n$ -components.

## LITERATURE

(For a key to the periodicals see end of volume)

- (1) Gale and Adams, *21*, 35: 10; 12. (2) King, *21*, 37: 239; 13. 39: 139; 14. 56: 318; 22. (3) Mount Wilson Obs., Pasadena, Calif., *0*. (4) Rowland, *21*, 1: 29, 131, 222, 295, 377; 95. 2: 45, 109, 188, 306, 360; 95. 3: 141, 201, 356; 96. (5) St. John and Ware, *21*, 39: 5; 14. (6) St. John *et al.*, 152, No. 396; 28. (7) Comm. Report., 538, 3: 93; 28.

## UNIDENTIFIED LINES AND BANDS IN CELESTIAL SPECTRA

F. E. BAXANDALL

In the following tables, only the stronger of the unidentified lines are given; others will be found in the articles quoted.

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TABLE 1.—CELESTIAL SOURCES OF UNIDENTIFIED LINES

For bands, v. Table 3

Sym. = symbol by which the source is indicated in Table 2; Scale max. = maximum of the intensity scale adopted by the authority indicated in the Lit. column; Min. included = lowest intensity, by that authority, which is included in Table 2; No. = number of lines from that source which is included in Table 2; they lie between  $\lambda_{\min}$  and  $\lambda_{\max}$ .

Unit of  $\lambda = 1 \text{ \AA} = 10^{-8} \text{ cm}$ .

Source	Sym.	Lit.	Scale max.	Min. included	No.	$\lambda_{\min}$	$\lambda_{\max}$
Aurora.....	A	(3, 28, 34)			3	5577	5578
Corona.....	Cor	(8)*	30	4	13	3328	6374
Chromosphere.....	Chr	(11)	100	3	48	3231	5780
		(16)	10	3			
		(21)	100	2			
		(19)	80	3			
Fraunhofer spectrum.....	Fra	(7)	2	1	31	3033	9638
		(18)					
		(26)	40	4			

TABLE 1.—(Continued)

Source	Sym.	Lit.	Scale max.	Min. included	No.	$\lambda_{\min}$	$\lambda_{\max}$
Planets.....	Pla	(27)			7	5093	6677
Nebulae.....	Neb	(37)	360	10	17	3426	6583
Nova Aquilae No. 3.....	NoA	(17)			1	4603	4603
Nova Geminorum No. 2.....	NoG	(2, 31)	8	5	2	4610	4639
Nova Persei.....	NoP	(14)	10	3	5	3868	4720
Wolf-Rayet stars.....	W-R	(23)	50	3	29	3414	5304
		(37)†	100	15			
v Sagittarii.....	Sag	(24)	4	2	5	3938	4278
36 $\pi$ Eridani.....	Eri	(23)	50	2	5	3954	4621
R. Aquarii.....	RAq	(19)			2	4658	4701
$\theta$ Aurigae.....	$\theta$ Au	(15)	10	3	5	3954	4376
$\alpha$ Canum Venaticorum.....	CaV	(5)			6	3983	4815
$\eta$ Carinae.....	Car	(22)	10	3	13	4244	4889
$\circ$ Ceti.....	Cet	(1)			24	3852	4838
		(12)					
		(32)	90	4			
		(29)	10	3			
$\alpha$ Cygni.....	Cyg	(38)			25	3020	4876
		(36)	5	2			
		(39)	4	3			
H. P. 1311 (A. G. C. 8631)	HP	(9)			2	4059	4606
$\epsilon$ Ursae Majoris.....	UMa	(30)	10	3	5	3911	4275

\* A summary of records of many observers. The  $\lambda$ 's are probable values as derived from the collective records. Scale max. of no observer exceeds 30. Every unidentified line recorded by any observer as of intensity  $\leq 4$  is included in Table 2.

† The record used is the spectrum of the nucleus of planetary nebula B D. + 30°, 3639, which contains almost all the lines of the Wolf-Rayet stars more sharply defined than in the Wolf-Rayet stars themselves.



TABLE 2.—UNIDENTIFIED LINES IN CELESTIAL SPECTRA

Only the stronger lines in the spectra of the sources listed in Table 1 are given. The symbol (*v.* Table 1) indicating the source is followed by a number indicating the authority (*v.* Lit.). Absorption lines are indicated by an *a* preceding the value of  $\lambda$ ; values in { probably refer to the same line. The wave-lengths of lines of  $\alpha$  Ceti recorded by Stebbins (32) and by Adams and Joy (1) have here been corrected for the mean velocity shift. For maximum of intensity scale, number of lines for each source, etc., *v.* Table 1. Sym. = symbol of the source, *I* = intensity,  $\lambda$  = wave-length. Unit of  $\lambda = 1$  Int. Å =  $10^{-8}$  cm (for reduction to Rowland's scale, *v.* Table 4).

Unit of  $\lambda = 1 \cdot \text{Int. } \text{\AA} = 10^{-8} \text{ cm}$  (for reduction to Rowland's scale, *v.* Table 4).

$\lambda$	Sym.	$I$	$\lambda$	Sym.	$I$	$\lambda$	Sym.	$I$	$\lambda$	Sym.	$I$
$\alpha$ 3020.2	Cyg (39)	3	3643	Cor (8)	5	$\alpha$ 4188.73	Fra (25)	4	$\alpha$ 4621.72	Eri (33)	2
$\alpha$ 3033.41	Fra (25)	5	3687	W-R (23)	4	$\alpha$ 4190.99	Eri (33)	2	4622	W-R (23)	10
$\alpha$ 3035.73	Fra (25)	5	3726.15*	Neb (37)	50	$\alpha$ 4191.6	$\theta$ Au (15)	3	4633.54	Cet (12)	
$\alpha$ 3038.8	Cyg (39)	3	3728.90*	Neb (37)	30	$\alpha$ 4198.24	Fra (25)	4	4634.76	Cet (12)	
$\alpha$ 3047.7	Cyg (39)	3	3734	W-R (23)	3	$\alpha$ 4200.5	Sag (24)	2	4636††	NoP (14)	3
$\alpha$ 3050.11	Fra (25)	4	$\alpha$ 3748.60	Cyg (38)	3	$\alpha$ 4200.5	$\theta$ Au (15)	3	4639.0††	NoG (31)	
$\alpha$ 3053.41	Fra (25)	7	3769	W-R (23)	3	$\alpha$ 4200.96	Eri (33)	4	4639.08	Cet (12)	
$\alpha$ 3059.52	Cyg (39)	3	3769.75	Cyg (38)	3	4229.4	W-R (37)	15	4658.2	RAq (19)	
$\alpha$ 3096.45	Cyg (39)	3	3813.5	W-R (23)	3	4231.2	Cor (8)	8	4666	W-R (37)	40
$\alpha$ 3125.27	Fra (25)	5	3852.21	Cet (32)	4	4233.15§	Cet (32)	12	4669.44	Chr (21)	2
$\alpha$ 3177.51	Cyg (39)	3	$\alpha$ 3859.95	Cyg (29)	3	4233.26§	Cet (12)		4698.72	Chr (11)	3
$\alpha$ 3231.32	Chr (10)	3	$\alpha$ 3867.20	Chr (10)	3	4244.09	Car (22)	8	$\alpha$ 4699.33	Fra (25)	4
$\alpha$ 3236.15	Chr (10)	3	3868	NoP (14)	10	$\alpha$ 4275.4	UMa (30)	3	$\alpha$ 4700.16	Fra (25)	4
$\alpha$ 3245.97	Fra (25)	4	3868.65	Neb (37)	70	4276.85	Car (22)	5	4701.4	RAq (19)	
$\alpha$ 3251.92	Fra (25)	4	$\alpha$ 3911.25	UMa (30)	3	$\alpha$ 4278.40	Sag (24)	2	4711.4	Neb (37)	10
$\alpha$ 3255	Cyg (38)	2	$\alpha$ 3936.90	Chr (10)	3	4287.29	Car (22)	10	4720	NoP (14)	6
$\alpha$ 3258	Cyg (38)	3	3938.05	Chr (16)	3	4291.48	Cet (12)		4728.17	Car (22)	5
$\alpha$ 3261.62	Fra (25)	4	3938.19	Cet (32)	8	$\alpha$ 4301.10	Fra (25)	4	4739	W-R (23)	3
$\alpha$ 3281.21	Cyg (38)	3	$\alpha$ 3938.40	Fra (25)	4	4302.78	Chr (11)	3	4740.2	Neb (37)	20
$\alpha$ 3285.60	Cyg (38)	2	$\alpha$ 3938.45	Cyg (29)	3	$\alpha$ 4303.94	Fra (25)	4	4756.54	Cet (12)	
$\alpha$ 3288.60	Chr (10)	3	$\alpha$ 3938.45	UMa (30)	3	4316.64	Chr (21)	2	4757.3	Chr (16)	3
$\alpha$ 3289.44	Cyg (38)	2	$\alpha$ 3938.60	Sag (24)	3	4325.6	W-R (37)	50	4761.8	Chr (16)	4
$\alpha$ 3308.81	Fra (25)	5	$\alpha$ 3945.05	Cyg (29)	3	4342.58	Car (22)	4	4768.27	Chr (21)	2
$\alpha$ 3324.06	Fra (25)	4	3952.15	Chr (16)	4	4343.09	Chr (21)	2	4786.2	W-R (37)	20
3328.1	Cor (8)	5	$\alpha$ 3954.15	$\theta$ Au (15)	4	4358.94	Car (22)	10	4801.15	Cet (12)	
$\alpha$ 3366.17	Chr (10)	3	$\alpha$ 3954.40	Eri (33)	2	4359	Cor (8)	6	4810.8	Chr (16)	3
3388	Cor (8)	30	3967.51	Neb (37)	70	4363.20	Neb (37)	80	4814.60	Car (22)	5
$\alpha$ 3407.22	Cyg (38)	2	3967.58	Cet (32)	8	4364	NoP (14)	7	$\alpha$ 4815	CaV (5)	
3414	W-R (23)	5	3969.86†	NoP (14)	10	4372.68	Cet (32)	9	4838.50	Cet (12)	
$\alpha$ 3416.11	Cyg (38)	2	$\alpha$ 3973.44	Chr (10)	4	$\alpha$ 4376.8	$\theta$ Au (15)	3	4849.15	Chr (21)	2
3426.3	Neb (37)	20	$\alpha$ 3983.85	CaV (5)		$\alpha$ 4377.44	Eri (33)	2	$\alpha$ 4876.5	Cyg (35)	3
$\alpha$ 3438.99	Chr (10)	4	3986.75	Cor (8)	5	4407.9	Chr (16)	3	4889.46	Car (22)	3
3445	Neb (37)	13	3991.15	Chr (16)	3	4413.87	Car (22)	8	4958.91	Neb (37)	200
3455	Cor (8)	8	4006.82	Cet (32)	9	4416.26¶	Car (22)	9	5006.84	Neb (37)	360
$\alpha$ 3465.74	Cyg (38)	2	4021.45	Chr (16)	3	4441.2	W-R (37)	40	$\alpha$ 5093	Pla (27)	
$\alpha$ 3468.71	Cyg (38)	2	$\alpha$ 4024.45	Cyg (29)	3	4446.38	Chr (11)	3	5130.7	W-R (37)	25
$\alpha$ 3468.77	Chr (10)	3	$\alpha$ 4032.96	Sag (24)	2	$\alpha$ 4448	CaV (5)		$\alpha$ 5210	Pla (27)	
$\alpha$ 3471.39	Chr (10)	3	$\alpha$ 4038	CaV (5)		4448.13	Cet (1)		5250.9	W-R (37)	20
$\alpha$ 3471.47	Cyg (38)	2	$\alpha$ 4040.90	Chr (10)	3	4451.94	Car (22)	6	5272.4	W-R (37)	15
$\alpha$ 3487.95	Chr (10)	3	$\alpha$ 4044.08	Sag (24)	2	4456.89	Cet (12)		5299.8	Chr (16)	3
$\alpha$ 3493.44	Cyg (38)	3	4049	W-R (23)	4	4457	W-R (37)	20	5302.9	Cor (8)	20
$\alpha$ 3513.93	Fra (25)	4	4056.55	W-R (37)	55	4457.80	Car (22)	5	5304.8	W-R (37)	15
$\alpha$ 3561.67	Chr (10)	3	4059†	HP (9)	10	4458.62	Cet (12)		5425.29	Chr (21)	4
$\alpha$ 3570.27	Fra (25)	4	4068.62	Neb (37)	60	4462.1	Chr (16)	3	$\alpha$ 5428	Pla (27)	
$\alpha$ 3572.47	Fra (25)	4	4070	W-R (37)	55	$\alpha$ 4465.6	W-R (37)		5477.00	Chr (11)	3
$\alpha$ 3573.74	Chr (10)	3	$\alpha$ 4076	CaV (5)		4474.70	Car (22)	3	5490.71	Chr (21)	2
$\alpha$ 3576.32	Fra (25)	4	$\alpha$ 4076.15	$\theta$ Au (15)	3	4496.6	Chr (16)	3	5577.35	A (3)	
$\alpha$ 3585.33	Cyg (38)	3	4076.22	Neb (37)	20	4511.56	Cet (12)		5577.83	A (28)	
3601.15	Cor (8)	15	4086	Cor (8)	6	$\alpha$ 4516	CaV (5)		5578.0	A (34)	
3611	W-R (37)		4086.55	Chr (16)	3	4516.4	W-R (37)	50	5669.3	Chr (16)	3
3631	W-R (23)	3	$\alpha$ 4105.05	Chr (10)	4	4518.30	Chr (21)	3	5755	Neb (37)	20
3640.5	W-R (23)	3	$\alpha$ 4109.35	Chr (10)	3	4521.37	Cet (12)		$\alpha$ 5762	Pla (27)	
						4555	W-R (37)	20	5780.6	Chr (16)	4
						4559.70	Cet (12)		$\alpha$ 5973	Pla (27)	



$\lambda$	Sym.	<i>I</i>	$\lambda$	Sym.	<i>I</i>
$\alpha$ 6191	Pla (27)		$\alpha$ 7691.58	Fra (18)	2
6302	Neb (37)	10	$\alpha$ 8648.41	Fra (18)	2
6374	Cor (8)		$\alpha$ 9095.01	Fra (7)	1
6548.1††	Neb (37)	70	$\alpha$ 9255.87	Fra (7)	1
6583.6††	Neb (37)	110	$\alpha$ 9415.07	Fra (7)	1
$\alpha$ 6677	Pla (27)		$\alpha$ 9556.11	Fra (7)	2
$\alpha$ 7165.57	Fra (18)	2	$\alpha$ 9638.45	Fra (7)	1

\* Theoretically identified as OII lines (\*).

† Much too strong to be due solely to H $\epsilon$ .

‡ Described by Harvard observers as double, the more refrangible component being the wider and fainter.

§ In  $\alpha$  Ceti the bright lines other than those of H are generally considered to be lines of low temperature, hence these lines can not be identified with the enhanced Fe lines at 4233.33 and 4583.90.

|| Theoretically identified as OIII lines (\*).

¶ Probably involves enhanced Fe lines 4417.00; all the other prominent enhanced Fe lines occur in  $\eta$  Carinae.

\*\* Probably identical in origin and  $\lambda$ ; broad and hazy; possibly, but not surely, identical with oxygen line 4609.40 which appears to behave differently from other O lines.

†† These two  $\lambda$ 's, obtained from different records, probably refer to the same line; line is broad and diffuse, and occurred in the later stages of the Novae.

‡‡ As neighboring C line at 6577.5 does not appear in nebular spectra, 6583.6 is probably not the C line at 6583.0; it and 6548.1 are probably of gaseous origin, like the great majority of nebular lines of known origin. Both have been theoretically identified as NII lines (\*).

TABLE 3.—HEADS OF UNIDENTIFIED BANDS

For additional information and list of possible bands in sun-spot spectra, v. (4). R indicates that the band extends from the head towards the red end of the spectrum, V towards the violet. Unit of  $\lambda = 1 \text{ \AA} = 10^{-8} \text{ cm}$ .

$\lambda$		Source	Lit.
4313.2*	R	$\alpha$ Ceti.....	(32)
4395.4	V	R types.....	(26)
4409.2	V	R types.....	(26)
4640†	R	S types and R Cygni.....	(20, 36)
4713.0	R	$\alpha$ Ceti.....	(32)
4736.9†	R	$\alpha$ Herculis.....	(32)
4752.8§	V	N types.....	(13)
4841.6	R	$\alpha$ Ceti.....	(32)
4855.3	V	132 Schjellerup, etc.....	(13)
4871.4	R	152 Schjellerup, etc.....	(13)
4890.1	V	N types.....	(13)
4891.9	V	R types.....	(26)
4900.9	R	78 Schjellerup, etc.....	(13)
4906	R	152 Schjellerup, etc.....	(13)
5438.1	R	$\alpha$ Ceti.....	(32)
5550†	R	R Cygni.....	(20, 36)
5721.2	R	115 Schjellerup, etc.....	(13)

\* Not the hydrocarbon band 4314.

† Not the "Swan" band 4737.

‡ Probably due to ZrO.

§ Probably due to a C compound.

TABLE 4.—CONVERSION TO ROWLAND'S SCALE  
 $\lambda$  on International scale +  $C = \lambda$  on Rowland's scale. Unit of  $\lambda$  and  $C = 1 \text{ \AA} = 10^{-8} \text{ cm}$

Range of $\lambda$	$C$	Range of $\lambda$	$C$
2950 to 3125	0.12	5400 to 5500	0.21
3125 to 3250	0.13	5500 to 6050	0.22
3250 to 3450	0.14	6050 to 6500	0.21
3450 to 4150	0.15	6500 to 6570	0.22
4150 to 4350	0.16	6570 to 6750	0.23
4350 to 4550	0.17	6750 to 6850	0.24
4550 to 5125	0.18	6850 to 7000	0.25
5125 to 5300	0.17	7000 to 7200	0.26
5300 to 5325	0.18	7200 to 7400	0.27
5325 to 5375	0.19	7400 to 7700	0.28
5375 to 5400	0.20		

## LITERATURE

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## LOW-TEMPERATURE LUMINESCENCE

E. L. NICHOLS AND E. MERRITT

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Luminescence at low temperatures ( $<1000^{\circ}\text{C}$ ) may be produced by light, X-rays, cathode rays, radioactive radiations, chemical reaction, or as a continuing after-effect of a luminescence due to any cause. That which persists for a time after the withdrawal of the exciting cause is generally called *phosphorescence*; that which exists during the excitation is often called *fluorescence*, but in this section that term is restricted to the cases in which the luminescence is produced by light, X-rays, or  $\gamma$ -rays.

Some substances can be caused to luminesce when pure, others only when they contain an activating impurity, generally a metal. The nature of the luminescence depends upon both the substance and the impurity, and its intensity varies rapidly as the concentration of the latter is increased, passing through a maximum and finally becoming zero while the concentration is still low. Cf. Table 8; see also (6).

TABLE 1.—INTENSITY OF LUMINESCENCE

For variation with concentration, see Table 8

$B_0$  = brightness of luminescence immediately after withdrawal of exciting radiation. Its value depends upon the intensity and the spectral distribution of the exciting radiation, and the latter affects the ratio of the values of  $B_0$  for any two substances.  $B_r$  = relative brightness of the luminescence when ozone is passed through the solutions at a fixed rate.  $f$  = fluid solution,  $s$  = solid. Unit of  $B_0$  = 1 millilambert = 0.001 lambert; of  $B_r$  is arbitrary.

Chemiluminescence when ozone is passed through solutions of esculin ( $\text{C}_{15}\text{H}_{16}\text{O}_9$ ) (14); (for N and P-vapor, see Table 9)

Solvent	$B_r$	Solvent	$B_r$
$\text{H}_2\text{O}$ , Water.....	1	$\text{C}_2\text{H}_5\text{O}$ , Acetone.....	3
$\text{CH}_3\text{O}$ , Methyl alcohol.....	3	$\text{C}_3\text{H}_7\text{O}$ , Propyl alcohol.....	5
$\text{C}_2\text{H}_5\text{O}$ , Ethyl alcohol.....	5	$\text{C}_3\text{H}_8\text{O}_3$ , Glycerol.....	0

Fluorescence excited by Fe-spark with light-filter transmitting the region between  $\text{ca. } \lambda = 0.3\mu$  and  $\lambda = 0.4\mu$  (22)

Substance	$B_0$
$\text{C}_{20}\text{H}_{12}\text{O}_5$	
Fluorescein (4.2 to 5.2)....	$f$ 4.7
Luciferin (14.5 to 16)....	$f$ 15.2
$\text{C}_{12}\text{H}_7\text{NO}_3$	
Resorufin.....	$f$ 3.0
Rhodamine 6G (4.2 to 12)....	$f$ 8.1
Rhodamine B.....	$f$ 5.2
Tetrachloro eosin.....	$f$ 4.2
ZnS	
Sidot blende (3.08 to 10.9)....	$s$ 7
$\text{Zn}_2\text{SiO}_4$	
Willemite (synthetic) (12.5 to 14).....	$s$ 13.2
$\text{Zn}_2\text{SiO}_4$	
Willemite (natural).....	$s$ 5.3
$\text{Cd}_3(\text{PO}_4)_2$	
Cadmium phosphate.....	$s$ 0.0182
Uranium glass.....	$s$ 7.31

TABLE 1.—(Continued)

Substance	$B_0$
$(\text{NH}_4)_2\text{UO}_2(\text{SO}_4)_2$	
$\text{NH}_4$ uranyl sulfate.....	$s$ 23.0
$\text{UO}_2(\text{NO}_3)_2 \cdot 6\text{H}_2\text{O}$	
Uranyl nitrate.....	$s$ 6.61
$\text{UO}_2(\text{C}_2\text{H}_3\text{O}_2)_2$	
Uranyl acetate.....	$s$ 5.39
$\text{PbUO}_2(\text{C}_2\text{H}_3\text{O}_2)_4 \cdot 4\text{H}_2\text{O}$	
Pb uranyl acetate.....	$s$ 3.75
CaS	
Balmain's paint.....	$s$ 1.26
$\text{CaCO}_3$	
Calcite.....	$s$ 0.132
$\text{K}_2\text{UO}_2\text{F}_6$	
K uranyl fluoride.....	$s$ 4.69
$\text{K}_2\text{UO}_2(\text{SO}_4)_2 \cdot 2\text{H}_2\text{O}$	
K uranyl sulfate.....	$s$ 35.2
$\text{KUO}_2(\text{NO}_3)_3$	
K uranyl nitrate.....	$s$ 7.53
$\text{Rb}_2\text{UO}_2\text{Cl}_4 \cdot 2\text{H}_2\text{O}$	
Rb uranyl chloride.....	$s$ 8.11
$\text{CsUO}_2(\text{NO}_3)_3$	
Cs uranyl nitrate.....	$s$ 5.71
$\text{CsUO}_2(\text{C}_2\text{H}_3\text{O}_2)_3$	
Cs uranyl acetate.....	$s$ 4.56

TABLE 2.—WAVE-LENGTHS ( $\lambda$ ) OF CRESTS OF BANDS: PHOTOLUMINESCENCE

For ultra-violet luminescence of 128 organic compounds in alcoholic solution, see (19)

In some cases only the principal bands are here listed.  $C$  = concentration, parts by weight or fraction of normal ( $N$ );  $N$  = normal concentration; Hg-arc = Hg arc in quartz tube. Tabular values are  $\lambda_0$ . Solvent is ethyl alcohol ( $\text{C}_2\text{H}_5\text{OH}$ ) unless otherwise indicated. Unit of  $\lambda = 1 \text{ \AA} = 10^{-8} \text{ cm}$ ;  $\Delta(1/\lambda) = \text{cm}^{-1}$ .

<p><math>\text{C}_6\text{H}_6</math>, Benzene  <math>C = \frac{1}{2000}</math>; Zn-spark (8)            2599, 2635, 2679, 2754, 2827, 2910.</p> <p><math>C = \frac{1}{2000}</math>; Hg-arc (33)            2700, 2757, 2829, 2943.  <math>C = 0.05N</math>; <math>t = -193^{\circ}\text{C}</math>; Hg-arc (18)            3390, 3460, 3520, 3570, 3650, 3710, 3800, 3850, 3970, 4020, 4130, 4190, 4290, 4350.</p> <p><math>\text{C}_6\text{H}_5\text{O}</math>, Phenol  <math>C = \frac{1}{2000}</math>; Zn-spark (8); 2776  <math>C = 0.05N</math>; <math>t = -193^{\circ}\text{C}</math>; Hg-arc (18)            3510, 3610, 3710, 3830, 3960, 4080.</p> <p><math>\text{C}_6\text{H}_5\text{O}_2</math>, Hydroquinol  <math>C = \frac{1}{2000}</math>; Zn-spark (8); 3032</p> <p><math>\text{C}_6\text{H}_5\text{O}_2</math>, Resorcinol  <math>C = (?)</math>; Hg-arc (33); 3000</p> <p><math>\text{C}_6\text{H}_7\text{N}</math>, Aniline  <math>C = \frac{1}{2000}</math>; Zn-spark (8); 3084  <math>C = 0.05N</math>; <math>t = -190^{\circ}\text{C}</math>; Hg-arc (16, 17)            3720, 3830, 3960, 4110, 4240.</p> <p><math>\text{C}_7\text{H}_5\text{N}</math>, Benzonitrile  <math>C = 0.05N</math>; Hg-arc (16, 17)            3790, 3810, 3870, 3950, 4050, 4120, 4210, 4310, 4410, 4510.</p> <p><math>\text{C}_7\text{H}_5\text{O}_2</math>, Benzoic acid  <math>C = 0.05N</math>; Hg-arc (16, 17)            3660, 3790, 3910, 4050, 4160.</p>	<p><math>\text{C}_7\text{H}_5\text{O}_3</math>, <i>p</i>-Hydroxybenzoic acid  <math>C = 0.05N</math>; Hg-arc (16, 17)            3790, 3920, 4050, 4210, 4330.</p> <p><math>\text{C}_7\text{H}_8</math>, Toluene  <math>C = \frac{1}{2000}</math>; Zn-spark (8)            2622, 2646, 2676, 2740, 2809, 2886.  <math>C = 0.05N</math>; <math>t = -193^{\circ}\text{C}</math>; Hg-arc (18)            3460, 3580, 3650, 3800, 3890, 4060, 4120.</p> <p><math>\text{C}_7\text{H}_5\text{O}</math>, <i>o</i>-Cresol  <math>C = 0.05N</math>; <math>t = -193^{\circ}\text{C}</math>; Hg-arc (18)            3530, 3630, 3740, 3850, 3970.</p> <p><math>\text{C}_7\text{H}_5\text{O}</math>, <i>m</i>-Cresol            3540, 3620, 3730, 3850, 3970, 4080.</p> <p><math>\text{C}_7\text{H}_5\text{O}</math>, <i>p</i>-Cresol            3630, 3730, 3850, 3980, 4110.</p> <p><math>\text{C}_7\text{H}_7\text{N}</math>, Benzylamine  <math>C = 0.05N</math>; <math>t = -190^{\circ}\text{C}</math>; Hg-arc (16, 17)            3470, 3600, 3670, 3800, 3910.</p> <p><math>\text{C}_8\text{H}_5\text{O}_4</math>, <i>o</i>-Phthalic acid  <math>C = (?)</math>; Hg-arc (33); 3100</p> <p><math>\text{C}_8\text{H}_7\text{N}</math>, <i>o</i>-Tolunitrile  <math>C = 0.05N</math>; <math>t = -190^{\circ}\text{C}</math>; Hg-arc (16, 17)            3750, 3800, 3930, 4000, 4110, 4180, 4260.</p>
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TABLE 2.—(Continued)

<b>C<sub>8</sub>H<sub>7</sub>N</b> , <i>m</i> -Tolunitrile 3790, 3910, 3960, 4050, 4160, 4220, 4290, 4440, 4550, 4650.
<b>C<sub>8</sub>H<sub>7</sub>N</b> , <i>p</i> -Tolunitrile 3770, 3890, 3950, 4020, 4150, 4220, 4290, 4450, 4520, 4600.
<b>C<sub>8</sub>H<sub>8</sub>O<sub>2</sub></b> , Phenylacetic acid $C = 0.05N$ ; $t = -190^{\circ}\text{C}$ ; Hg-arc (16, 17) 3440, 3570, 3640, 3790, 3860.
<b>C<sub>8</sub>H<sub>8</sub>O<sub>2</sub></b> , <i>o</i> -Toluic acid $C = 0.05N$ ; $t = -190^{\circ}\text{C}$ ; Hg-arc (16, 17) 3670, 3790, 3920, 4040.
<b>C<sub>8</sub>H<sub>8</sub>O<sub>2</sub></b> , <i>m</i> -Toluic acid 3740, 3860, 4000, 4120, 4250.
<b>C<sub>8</sub>H<sub>8</sub>O<sub>2</sub></b> , <i>p</i> -Toluic acid 3730, 3840, 3980, 4100, 4240.
<b>C<sub>8</sub>H<sub>10</sub></b> , <i>o</i> -Xylene $C = \frac{1}{2}000$ ; Zn-spark (8) 2603, 2636, 2680, 2713, 2793, 2896, 2986, 3038, 3135. $C = 0.05N$ ; $t = -193^{\circ}\text{C}$ ; Hg-arc (18) 3480, 3560, 3610, 3670, 3790, 3830, 3900, 4000, 4070, 4130.
<b>C<sub>8</sub>H<sub>10</sub></b> , <i>m</i> -Xylene (8) 2685, 2715, 2802. (18) 3540, 3610, 3670, 3730, 3820, 3880, 3970, 4090, 4160, 4230.
<b>C<sub>8</sub>H<sub>10</sub></b> , <i>p</i> -Xylene (8) 2681, 2739, 2801, 2865. (18) 3550, 3650, 3700, 3770, 3890, 3950, 4010, 4120, 4190, 4270.
<b>C<sub>8</sub>H<sub>10</sub></b> , Ethylbenzene $C = 0.05N$ ; $t = -193^{\circ}\text{C}$ ; Hg-arc (18) 3450, 3580, 3640, 3780, 3870, 4050, 4120.
<b>C<sub>8</sub>H<sub>10</sub>O</b> , <i>o</i> -Methylcresol $C = 0.05N$ ; $t = -193^{\circ}\text{C}$ ; Hg-arc (18) 3550, 3620, 3760, 3850.
<b>C<sub>8</sub>H<sub>10</sub>O</b> , <i>m</i> -Methylcresol 3570, 3660, 3770, 3900, 4000.
<b>C<sub>8</sub>H<sub>10</sub>O</b> , <i>p</i> -Methylcresol 3660, 3770, 3900, 4000, 4120.
<b>C<sub>8</sub>H<sub>10</sub>O</b> , Xylenol $C = 0.05N$ ; Hg-arc (16, 17) 3570, 3660, 3780, 3890, 4010.
<b>C<sub>8</sub>H<sub>7</sub>N</b> , Quinoline $C = \frac{1}{2}000$ ; Zn-spark (8); 3840
<b>C<sub>8</sub>H<sub>12</sub></b> , Propylbenzene $C = 0.05N$ ; $t = -193^{\circ}\text{C}$ ; Hg-arc (18) 3440, 3580, 3650, 3790, 3890, 4050, 4130.

<b>C<sub>9</sub>H<sub>12</sub></b> , Mesitylene $C = \frac{1}{2}000$ ; Zn-spark (8) 2698, 2712, 2747, 2786, 2863, 2972. $C = 0.05N$ ; $t = -190^{\circ}\text{C}$ ; Hg-arc (16, 17) 3570, 3620, 3690, 3760, 3850, 3920, 4000.
<b>C<sub>9</sub>H<sub>12</sub></b> , Pseudocumene $C = 0.05N$ ; $t = -190^{\circ}\text{C}$ ; Hg-arc (16, 17) 3560, 3650, 3770, 3880, 4000, 4120, 4270.
<b>C<sub>10</sub>H<sub>8</sub></b> , Naphthalene $C = \frac{1}{2}000$ ; Hg-arc (33) 3157, 3223, 3269, 3320, 3349, 3386, 3457, 3500, 3537. $C = \frac{1}{2}000$ ; Zn-spark (8) 3000, 3046, 3098, 3142, 3190, 3235, 3292, 3340, 3386, 3447, 3498, 3558, 3627, 3654.
<b>C<sub>10</sub>H<sub>8</sub>O</b> , $\alpha$ -( $\beta$ )-Naphthol $C = \frac{1}{2}000$ ; Zn-spark (8) $\lambda_{\alpha} = 3185$ , 3250, 3379; $\lambda_{\beta} =$ 3274, 3348.
<b>C<sub>10</sub>H<sub>9</sub>N</b> , $\alpha$ -( $\beta$ )-Naphthylamine $C = \frac{1}{2}000$ ; Zn-spark (8) $\lambda_{\alpha} = 3553$ ; $\lambda_{\beta} = 3579$ .
<b>C<sub>10</sub>H<sub>14</sub></b> , Cymene $C = 0.05N$ ; $t = -190^{\circ}\text{C}$ ; Hg-arc (16, 17) 3530, 3640, 3730, 3850, 3970.
<b>C<sub>12</sub>H<sub>10</sub></b> , Diphenyl $C = \frac{1}{2}000$ ; Zn-spark (8) 2864, 2893, 2921, 2966, 3022, 3113, 3186, 3321.
<b>C<sub>12</sub>H<sub>11</sub>N</b> , Diphenylamine $C = \frac{1}{2}000$ ; Zn-spark (8); 3158
<b>C<sub>13</sub>H<sub>12</sub></b> , Diphenylmethane $C = \frac{1}{2}000$ ; Zn-spark (8) 2650, 2684, 2742, 2815, 3736, 3924, 4144.
<b>C<sub>14</sub>H<sub>8</sub>O<sub>6</sub></b> , Purpurin in ethyl ether (C <sub>4</sub> H <sub>10</sub> O) $C = (?)$ ; sunlight (31); 5440
<b>C<sub>14</sub>H<sub>10</sub></b> , Anthracene $C = \frac{1}{2}000$ ; Hg-arc (33) 3857, 4000, 4300, 4357. $C = \frac{1}{2}000$ ; Zn-spark (8) 3658, 3762, 3897, 4115, 4354.
<b>C<sub>14</sub>H<sub>10</sub></b> , Phenanthrene $C = \frac{1}{2}000$ ; Hg-arc (33) 3014, 3100, 3166, 3271, 3343, 3400, 3486, 3529, 3557, 3643, 3700, 3749, 3834, 3943, 4043, 4243, 4443. $C = \frac{1}{2}000$ ; Zn-spark (8) 2971, 2995, 3065, 3154, 3231, 3302, 3382, 3439, 3494, 3545, 3614, 3733, 3797, 3926, 3992, 4134, 4229.

<b>C<sub>14</sub>H<sub>10</sub>O</b> , Anthranol $C = \frac{1}{2}000$ ; Zn-spark (8) 2731, 2781, 2829, 2882, 2939, 2990, 3063, 3119, 3190, 3441, 3617, 3735, 3930, 4139.
<b>C<sub>15</sub>H<sub>16</sub>O<sub>9</sub></b> , Esculin $C = (?)$ ; white light (26); 4600
<b>C<sub>19</sub>H<sub>16</sub></b> , Triphenylmethane $C = \frac{1}{2}000$ ; Zn-spark (8) 2688, 2704, 2757, 2832, 3717, 3823, 4032, 4258.
<b>C<sub>20</sub>H<sub>8</sub>Br<sub>4</sub>O<sub>6</sub></b> , Eosin in water $C = (?)$ ; white light (26); 5800
<b>C<sub>20</sub>H<sub>8</sub>I<sub>4</sub>O<sub>6</sub></b> , Erythrosine in gelatin $C = (?)$ ; Hg-arc (32); 4150
<b>C<sub>20</sub>H<sub>12</sub>O<sub>6</sub></b> , Fluorescein in con- centrated H <sub>2</sub> SO <sub>4</sub> $C = \frac{1}{2}000$ ; Hg-arc (33) 3200, 4700, 5100.
<b>C<sub>20</sub>H<sub>14</sub>O<sub>4</sub></b> , Phenolphthalein $C = (?)$ ; Hg-arc (33); 3000
<b>C<sub>40</sub>H<sub>60</sub>N<sub>4</sub>O<sub>8</sub>S</b> , Quinine sulfate in water $C = (?)$ ; white light (26); 4370
<b>C<sub>40</sub>H<sub>60</sub>N<sub>4</sub>O<sub>8</sub>S</b> , Quinine sulfate $C = \frac{1}{2}000$ ; Zn-spark (8); 3355
<b>Cyanin</b> in gelatin $C = (?)$ ; Hg-arc (32); 4000
<b>C<sub>13</sub>H<sub>8</sub>O<sub>4</sub></b> , 3, 6- Dihydroxyxanthone $C = (?)$ ; Hg-arc (33); 4200
<b>Rhodamine</b> in water $C = (?)$ ; white light (26); 5540
<b>Pt(CN)<sub>2</sub></b> and double Pt-cyan- ides, Fe-spark gives same bands as cathode-rays (3), see Table 3.
<b>UO<sub>2</sub>SO<sub>4</sub></b> in water (13); $C = (?)$ 4918.3   5133.9   5369.4   5626.8 5160.2   5395.8   5654.0 5910.1   6219.5 5938.8
<b>UO<sub>2</sub>(NO<sub>3</sub>)<sub>2</sub></b> in water (13); $C = (?)$ 5069.6, 5301.5, 5554.6, 5832.9.

<b>UO<sub>2</sub>(NH<sub>4</sub>)<sub>2</sub>(SO<sub>4</sub>)<sub>2</sub></b> in water (13); $C = (?)$ 4912.6   5124.5   5355.4   5607.4 4934.7   5147.8   5380.1   5633.3 5881.1   6184.0 5908.0   6215.7
<b>Al<sub>2</sub>O<sub>3</sub></b> , Ruby in sunlight (5) $-190^{\circ}\text{C}$ (lines) 6918, 6932, 6976, * 6985, * 7006, 7036, group at 7060 to 7130. $+18^{\circ}\text{C}$ (bands) 6590, 6690, 6760, 6790, * 6926, 6941, group† 7016, 7046, 7060, * 7130.* $+225^{\circ}\text{C}$ (bands) 6610, 6945, 6960; 4 diffuse bands* at 7016 to 7130. * Not recorded in extraordinary spectrum. † Not recorded in ordinary spec- trum.
<b>CaCO<sub>3</sub></b> , Calcite; Fe-spark (25); 2 sets of bands; * for each, $\Delta(1/\lambda) = 420 \text{ cm}^{-1}$ . 5084, 5195, 5311, 5432, 5559, 5692, 5831, 5977, 6131, 6293, 6464. 5025, 5133, 5247, 5365, 5488, 5618, 5754, 5896, 6046, 6203, 6369, 6545. * Same sets for CaO excited by H-flame (12), and in cathodolumines- cence of CaO activated with Mn (34).
<b>NaUO<sub>2</sub>(C<sub>2</sub>H<sub>3</sub>O<sub>2</sub>)<sub>3</sub></b> , Sodium uranyl acetate in water (13). $C = (?)$ ; 6 sets of 5 bands; for each set, $\Delta\lambda^{-1} = \text{ca. } 851$ $\text{cm}^{-1}$ . 4732.5   4932.5   5148.6   5384.5 4950.2   5167.8   5404.5 4762.3   4964.9   5184.9   5424.0 4769.2   4972.1   5192.2   5431.6 4785.8   4990.2 4794.6   4999.2   5221.4   5463.5 5642.7   5663.4   5685.8   5694.6
<b>Na<sub>2</sub>UO<sub>2</sub>(SO<sub>4</sub>)<sub>2</sub></b> in water (13); $C = (?)$ 4891.5   5101.2   5330.0   5578.5 5125.4   5354.7   5604.6

TABLE 3.—WAVE-LENGTHS ( $\lambda$ ) OF LINES AND OF CRESTS OF  
BANDS: CATHODOLUMINESCENCE  
For effect of solvent upon wave-length of maximum brightness of  
solid solutions, see Fig. 1

B. P. = boiling point,  $d$  = diffuse,  $e$  = edge of band,  $f$  = fine, narrow band,  $g$  = gas or vapor,  $m$  = maximum,  $n$  = nebulous,  $s$  = strong,  $w$  = weak,  $D$  = very diffuse,  $D'$  = very, very diffuse, etc.; similarly for  $S$ ,  $S'$ ,  $S''$ ,  $W$ , and  $W'$ . Tabular values are  $\lambda$ ; bands unless lines are indicated. Unit of  $\lambda = 1 \text{ \AA} = 10^{-8} \text{ cm}$ .

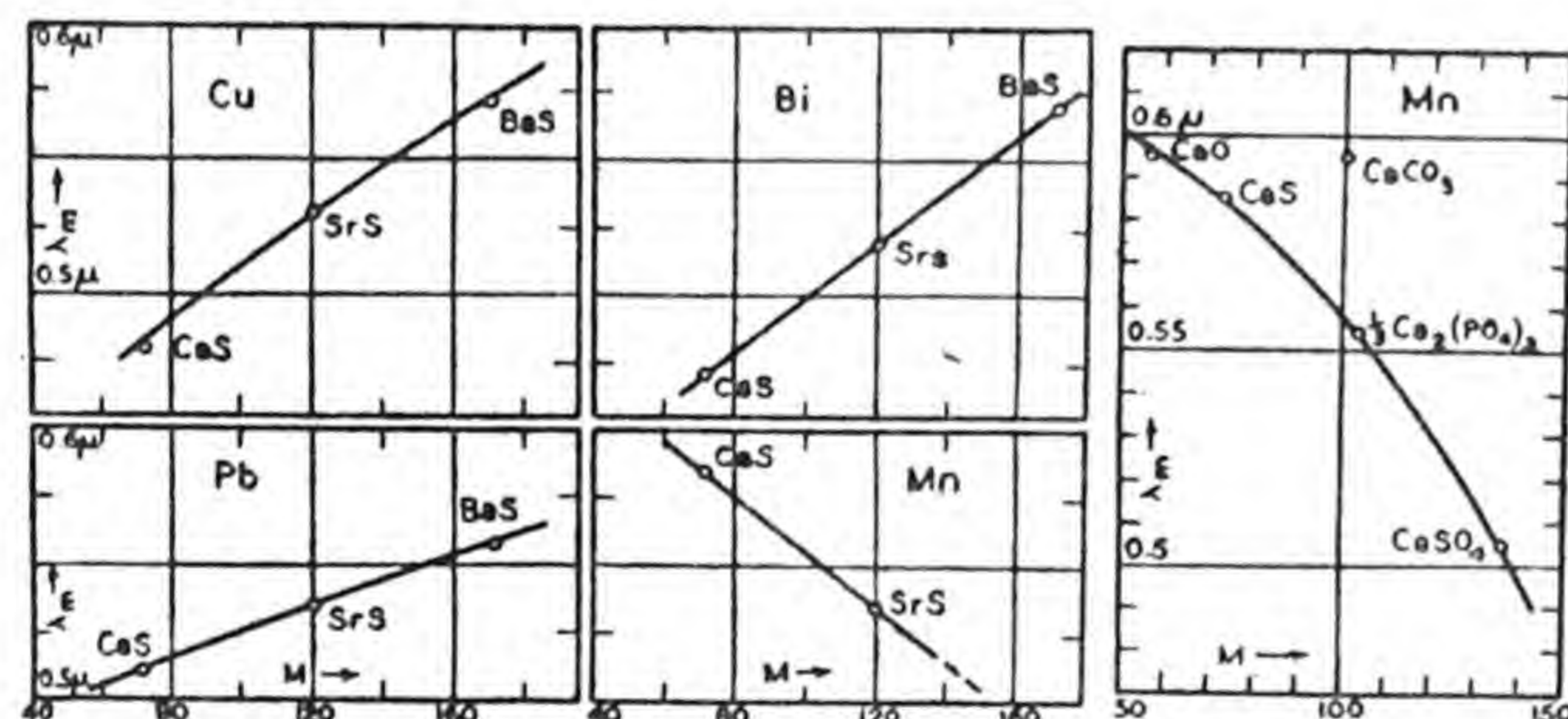
A (21) $g$ at B. P. of H: 5607.4S, 5648.3 Phosphorescence (afterglow): 4750s, 5350w					
Ca (15) $g$ lines coincide with arc lines but differ in intensity					
3179.50w	3181.43W	3630.87	3644.53	3706.18	3737.06s
3933.81S'	3957.22W	3968.63S'	3973.91	4108.60	4226.90S''
4240.61	4302.70w	4355.50s	4425.60	4435.17s	4435.88w
4455.00S	4456.10w	4527.35s	4581.77w	4586.22	4685.35
4878.38	5041.83w				

Cd (9, 20)  $g$  single line spectrum: 3260.17



TABLE 3.—(Continued)

Dy in $\text{Al}_2\text{O}_3$ ( $^{29}$ ) solid solution					
4478	4500	4519w	4545	4571s	4601
4694S	4709S	4721S	4761S	4768S	4788S
4809S	4837w	4861S'	4895	4919s	4924s
4940	4950s	4970S	4991w	5544w	5652
5680	5690w	5741w	5770	5803S	5818S
5833W	5880S	5891S	5945s	5961	6545W'
6720W					
Dy in $\text{CaO}$ ( $^{36}$ ) solid solution, concentration = 1 % $\text{Dy}_2\text{O}_3$					
4540	4728	4748	4797S	4890S	5708
5830*	5848S*	5958	6750S		
Dy in $\text{CaWO}_4$ ( $^{29}$ ) solid solution					
4479	4546s	4620W	4690D	4739	4782s
4868s	5063W	5212w	5342s	5449s	5490d
5511	5606	5656	5690s	5747S	5787s
5816s	6022W	6450W	6588sd	6662d	
Er in $\text{CaO}$ ( $^{36}$ ) solid solution, concentration = 1 % $\text{Er}_2\text{O}_3$					
4040S	4085S	4095	4460	4520	4550S
4590S	5280*	5330*	5595		
Eu in $\text{Al}_2\text{O}_3$ ( $^{29}$ ) solid solution					
5040wn	5438d	5584d	5509sd	5905sd	6158Sd
6304d	6588d	6930sd			
Eu in $\text{CaO}$ ( $^{36}$ ) solid solution, concentration = 1 % $\text{Eu}_2\text{O}_3$					
4160S	4195S	4245S	4260S	4330	4466
4490	4655	4685S	4755	5405	5895S
5930S	5970	6128S	6155*	6180*	6245S
Eu in $\text{CaWO}_4$ ( $^{29}$ ) solid solution; rose color					
4100e	5350m	5720e	5901	5952D	6061D
6110s	6148S	6199	6545D		
Fe ( $^{18}$ ) $\rho$ lines coincide with arc lines					
3440.762	3441.155	3570.273	3581.349s	3609.008w	3618.919w
3631.605w	3647.988w	3680.069W	3687.610W	3705.708w	3720.084S
3722.729w	3727.778W	3735.014s	3737.281s	3745.717s	3748.408
3749.631	3758.375	3763.945w	3767.341W	3813.100W	3815.987w
3820.586	3824.591	3826.027	3834.364w	3840.580W	3856.524
3860.055S	3878.720	3886.434	3920.410w	3923.054w	3928.075w
3930.450w	4045.975w	4308.081W	4325.939W	4383.720	4404.927W

FIG. 1.—Wave-length ( $\lambda_m$ ) of maximum intensity of cathodoluminescence of solid solutions: Effect of solvent ( $^{34}$ ).

In each section, the activating metal (Bi, Cu, Mn, or Pb), and at each point, the corresponding solvent is indicated. M = molecular weight of solvent.

Gd in $\text{CaO}$ ( $^{36}$ ) solid solution, concentration = 1 %					
3088.5*	3094.0*	3134.0†	3140.5†	3144.0†	3147.0S
3153.0S*	3155.5*	3158.5S*			

Hg ( $^{20}$ )  $\rho$  single line spectrum: 2536.72

Mg ( $^{20}$ )  $\rho$  single line spectrum: 2852.22

N ( $^{21}$ )  $\rho$  at B. P. of H: 5556S, 5617s, 5654

Phosphorescence (afterglow): 5231s

Na ( $^{29}$ )  $\rho$  lines; those marked N are attributed to nitrogen

3052.9	3055.4	3073.9	3077.4	3078.9w	3092.3s
3128.9	3134.9	3149.0	3158.8	3163.9	3169.2w
3189.4	3213.6	3225.8w	3235.0	3257.9	3274.1
3285.4s	3302.8	3304.8	3318.2	3327.6	3371s
3533.3s	3536.5	3576	3582	3631.6s	3710.8

Na.—(Continued)

3754.8	3805.1	3882.6	3884.8	3894.0Nw	3896.6N
3898.8N	3901.3N	3903N	3905N	3907N	3908.7N
3914Ns	4236	4248w	4252Nw	4256N	4259
4262Nw	4265Nw	4268Nw	4270Nw	4271.5Nw	4273.0Nw
4278.2	4308.7w	4321.4	4324.7	4341.1	4344.0
4389.4	4392.8	4404.8w	4418.6w	4421.9	4448w
4454.5w	4481.5	4484.5	4490w	4493.8	4497.3
4541.3	4544.8	4664.7s	4668.4s	4710w	4748.3
4752.2	4862w	4979.3s	4983.5s	5149.2	5153.7
5221.0w					
Bands:	5700	5744	5792	5843	5894
5946	6000	6053	6112	6164	6218
6276	6328	6388	6455	6515	6565
Nd in $\text{Al}_2\text{O}_3$ ( $^{29}$ ) solid solution					
3613n,	3634	3651n	3661w	3665d	3670d
3685w	3917w	3923e	3930e	3943S	4006s
4038S	4069S	4081s	4306e	4310e	4340s
4415e	4426e	4439e	4453e	4466e	4472e
4482e	4495e	4589e	4595e	4626e	4645e
4673w	4709s	4851	4884S	4913s	4948w
5305S	5505s	5672			
Nd in $\text{CaO}$ ( $^{36}$ ) solid solution, concentration = 1 % $\text{Nd}_2\text{O}_3$					
3920S	3980	4190S	4220S	4230S	4295S
4575S					
Nd in $\text{CaWO}_4$ ( $^{29}$ ) solid solution, continuous spectrum, blue					
Pr in $\text{CaO}$ ( $^{36}$ ) solid solution, concentration = 1 % $\text{Pr}_2\text{O}_3$					
4875S	4940	5170	6045S*	6065S*	6150†
6200†	6260S	6340S			
Pr in $\text{CaWO}_4$ ( $^{29}$ ) solid solution					
4756D	4874S	4989d	5092D	5189D	5284D
5324S	5412d	5495wd	5574w	5683sd	5748Wd
5773Wd	5940d	6034s	6100D	6194s	6278
6394	6500S	6540wd			
Pt(CN) $_2$ and double Pt-cyanides of Ba, Ca, K, K $_2$ Ca, KLi, KNa, Mg, NH $_4$ , Na, and Sr ( $^{35}$ ). Positions of bands are same for all, but relative intensities differ; positions depend upon hydration.					
Dehydrated salts:					
4740	5370	5780	6480	6560	
Salts not dehydrated:					
4720	4920	5340	5760	5920	6370
Sa in $\text{Al}_2\text{O}_3$ ( $^{29}$ ) solid solution					
4700n	4850n	5079W	5175W	5353wd	5440w
5465w	5550	5644S	5730S	5817s	5857w
5909	5990	6107S	6194S'	6230f	6265S
6387w	6505w	6618	6753		
Sa in $\text{CaO}$ ( $^{36}$ ) solid solution, concentration = 1 % $\text{Sa}_2\text{O}_3$					
5486	5561	5683S	5762S	6052S*	6150S*
6265	6605†	6740†			
Sa in $\text{CaWO}_4$ ( $^{29}$ ) solid solution					
5272e	5300m	5460e	5545d	5628s	5689d
5885d	5952S	5994S	6050S	6072S	6124d
6368d	6420S	6460S	6544d	7100w	7900W
Tb in $\text{Al}_2\text{O}_3$ ( $^{29}$ ) solid solution					
3532W	3543n	3565n	3591n	3611n	3646w
3653w	3660w	3685	3702s	3760s	3778s
3795s	3797	3812S	3828S	3847s	3853s
3889S	3906S'	3986e	4014	4029S	4099
4102S	4121e	4122w	4131w	4141s	4159s
4170w	4180	4191S	4212s	4229S	4230S'
4306	4330S	4369S	4392S''	4414S'	4437S'
4461S	4490S	4554	4600S	4606S	4664w
4743s	4767s	4788s	4813w	4832	4862S
4878s	5009	5018S'	5454n	5517S	5573S'
5807	5856	5886w	5920s	5989n	6264s
Tb in $\text{CaO}$ ( $^{36}$ ) solid solution, concentration = 1 % $\text{Tb}_2\text{O}_3$					
3770S	3787S	3805S	3880S	3900S	4180S
4190S	4200S	4210S	4350S	4370S	4395S
4855S	5425S	5495S*	5521S*	5550S	5843S
5878S	5955S	6017S	6330S		
Tb in $\text{CaWO}_4$ ( $^{29}$ ) solid solution					
3720W	3762w	3789	3819	3853	4100
4140s	4168	4243w	4311w	4332w	4355S
4379	4398	4427	4563	4588	4707
4738	4759	4859S	4879S	4906s	4961s
4990w	5425e	5458S'	5491S'	5517s	5808
5839	5881S	5891s	5951	5979W	6168s
6214S	6257s	6293d	6412d	6466d	6542
6717s	6822W	7400W			
Zn ( $^{20}$ ) $\rho$ single line spectrum: 3075.99					

\* Overlaps the similarly marked adjacent band.

† Overlaps the similarly marked adjacent band.



TABLE 4.—WAVE-LENGTHS ( $\lambda$ ) OF CRESTS OF BANDS:

## CHEMILUMINESCENCE

Certain chemical reactions proceeding at low temperatures give rise to luminescence. The bands recorded below are due to oxidation. *s, w* = strong, weak; *S, W* = very strong, very weak. Tabular values are;  $\lambda$  unit =  $1 \text{ \AA} = 10^{-8} \text{ cm}$ .

## P, Phosphorus (7)

2381W	2387W	2398s	2454s	2458S	2474S
2507W	2517W	2531W	2544W	2579W	2587W
2613W	3339W				

For brightness and efficiency of luminescence of N saturated with P-vapor, see Table 9.

$\text{C}_6\text{H}_4\text{O}_3$ , Pyrogallol (30); 4590 (width = 350  $\text{\AA}$ )

TABLE 5.—WAVE-LENGTHS ( $\lambda$ ) OF CRESTS OF BANDS:

## LUMINESCENCE EXCITED BY FLAMES, X-RAYS, AND RADIATIONS FROM RADIOACTIVE SUBSTANCES

Fl, X, RR = excitation by flame, X-rays, radioactive radiations. C, Diamond (30) RR: 4030, 4120, 5510  
 $\text{Cb}_2\text{O}_6$ , Fl(23) two sets of bands: 4831, 5500, 6748; and 5020, 5747, 6196.

$\text{BaPt}(\text{CN})_4$	RR (30)	5430 to 6040	wide crest
$\text{BaPt}(\text{CN})_4$	X (2)	continuous spectrum*	
$\text{BaSO}_4$	X (28)	3120 to 4760	crest 3640
		2700 to 5000	crest 3830*
$\text{CaPt}(\text{CN})_4$	RR (30)	4770 to 5170	crest 4900
$\text{CaI}_2$	X (28)	4170 to 5000	crest 4570
		5130 to 5880	crest 5520
$\text{CuI}_2$	X (28)	4080 to 4760	crest 4350
$\text{HgI}_2$	X (28)	5400 to 5710	crest 5560
$\text{KLiCl}_2$	X (28)	2780 to 3330	crest 3100
		3850 to 5000	crest 4500
$\text{K}_2\text{Pt}(\text{CN})_4$	X (2)	continuous spectrum	
$\text{KLiPt}(\text{CN})_4$	RR (30)	5550 to 5970	crest 5760
$\text{KNaPt}(\text{CN})_4$	RR (30)	5340 to 5790	crest 5670
$\text{Li}_2\text{Pt}(\text{CN})_4$	X (2)	continuous spectrum	
$\text{LiRbPt}(\text{CN})_4$	RR (30)	5400 to 5820	crest 5590
$\text{MgPt}(\text{CN})_4$	X (2)	continuous spectrum	
$(\text{NH}_4)_2\text{Pt}(\text{CN})_4$	X (2)	continuous spectrum	
$\text{Rb}_2\text{Pt}(\text{CN})_4$	RR (30)	4600 to 4850	crest 4760
$\text{Rb}_2\text{Pt}(\text{CN})_4$	X (2)	continuous spectrum	
$\text{Th}[\text{Pt}(\text{CN})_4]_2$	X (2)	continuous spectrum	
$\text{ZnO}$	X (28)	4350 to 5130	crest 4830
		5400 to 5880	crest 5630

\* Exposure twice as long as for preceding entry.

TABLE 6.—FLAME EXCITATION: TEMPERATURE LIMITS (27)

Certain substances luminesce below  $1000^\circ\text{C}$  when placed in that portion of a H-flame which lies between the reducing and the oxidizing zones. The temperature limits ( $t_1$  and  $t_2$ ) between which luminescence occurs, and the color of the luminescent bands are given below.

Substance	$t_1, ^\circ\text{C}$	$t_2, ^\circ\text{C}$	Color
$\text{Al}_2\text{O}_3$	55	692	Pale green
$\text{CaF}_2$	58	310	Yellow-green
$\text{CaO}$	0	600	Red
$\text{CaO}$	40	725	Green
$\text{CaS}$	60	330	Blue-green
$\text{Cb}_2\text{O}_6$	(?)	(?)	see Table 5
$\text{Cd}_3(\text{PO}_4)_2$	50	733	Yellow
$\text{MgO}$	75	680	Blue-green
$\text{SiO}_2$	85	367	White
$\text{ZnO}$	568	704	Red
$\text{ZnO}$	704	948	Green
$\text{ZnS}$	0	123	Yellow
$\text{ZnS}$	211	575	Blue-green
$\text{ZrO}_2$	76	372	Blue-green
$\text{ZrO}_2$	440	720	Red

TABLE 7.—FREQUENCY INTERVALS BETWEEN BANDS

$\Delta_a[\Delta_l]$  = interval in  $1/\lambda$  between adjacent members of a set of bands in the absorption [luminescent] spectrum. Frequency intervals are  $c\Delta_a$  and  $c\Delta_l$ . Unit of  $\Delta_a$  and of  $\Delta_l = 1 \text{ cm}^{-1}$   
 Uranyl ( $\text{UO}_2$ ) compounds (24); for absorption, see (4)

Compound	$\Delta_l$	$\Delta_a$
$\text{Cs}_2\text{UO}_2\text{Cl}_4$	834.4	705.4
$\text{K}_2\text{UO}_2\text{Cl}_4 \cdot 2\text{H}_2\text{O}$	835.8	702.2
$(\text{NH}_4)_2\text{UO}_2\text{Cl}_4 \cdot 2\text{H}_2\text{O}$	833.2	710.6
$\text{Rb}_2\text{UO}_2\text{Cl}_4 \cdot 2\text{H}_2\text{O}$	835.0	708.4
$\text{UO}_2\text{SO}_4 \cdot 3\text{H}_2\text{O}$	852.0	696.0
$\text{Cs}_2\text{UO}_2(\text{SO}_4)_2 \cdot 2\text{H}_2\text{O}$	857.0	704
$\text{K}_2\text{UO}_2(\text{SO}_4)_2 \cdot 2\text{H}_2\text{O}$	830.0	703.0
$(\text{NH}_4)_2\text{UO}_2(\text{SO}_4)_2 \cdot 2\text{H}_2\text{O}$	837.0	703.0
$\text{Na}_2\text{UO}_2(\text{SO}_4)_2 \cdot 3\text{H}_2\text{O}$	843.0	713.0
$\text{Rb}_2\text{UO}_2(\text{SO}_4)_2 \cdot 2\text{H}_2\text{O}$	832.0	698.0
$\text{UO}_2(\text{NO}_3)_2 \cdot 6\text{H}_2\text{O}$	859.0	714.3
$\text{NH}_4\text{UO}_2(\text{NO}_3)_3$	877.0	743.7
$(\text{NH}_4)_2\text{UO}_2(\text{NO}_3)_4 \cdot 2\text{H}_2\text{O}$	842.8	698.7
$\text{KUO}_2(\text{NO}_3)_3$	869.0	730.7
$\text{K}_2\text{UO}_2(\text{NO}_3)_4$	867.2	734.0
$\text{UO}_2(\text{C}_2\text{H}_3\text{O}_2)_2$ (acetate)	859.6	710.4
$\text{UO}_2(\text{C}_2\text{H}_3\text{O}_2)_2 \cdot 2\text{H}_2\text{O}$	857.2	723.5
$\text{AgUO}_2(\text{C}_2\text{H}_3\text{O}_2)_3$	847.4	700.1
$\text{Ba}(\text{UO}_2)_2(\text{C}_2\text{H}_3\text{O}_2)_6 \cdot 6\text{H}_2\text{O}$	850.8	713.6
$\text{Ca}(\text{UO}_2)_2(\text{C}_2\text{H}_3\text{O}_2)_6 \cdot 8\text{H}_2\text{O}$	838.8	705.4
$\text{KUO}_2(\text{C}_2\text{H}_3\text{O}_2)_3$	845.7	691.8
$\text{LiUO}_2(\text{C}_2\text{H}_3\text{O}_2)_3 \cdot 3\text{H}_2\text{O}$	845.0	702.7
$\text{Mg}(\text{UO}_2)_2(\text{C}_2\text{H}_3\text{O}_2)_6 \cdot 7\text{H}_2\text{O}$	851.9	706.0
$\text{MnUO}_2(\text{C}_2\text{H}_3\text{O}_2)_4 \cdot 6\text{H}_2\text{O}$	851.9	712.5
$\text{NH}_4\text{UO}_2(\text{C}_2\text{H}_3\text{O}_2)_3$	844.0	701.9
$\text{NaUO}_2(\text{C}_2\text{H}_3\text{O}_2)_3$	852.2	704.6
$\text{PbUO}_2(\text{C}_2\text{H}_3\text{O}_2)_4 \cdot 4\text{H}_2\text{O}$	851.2	712.1
$\text{RbUO}_2(\text{C}_2\text{H}_3\text{O}_2)_3$	848.6	707.8
$\text{Sr}(\text{UO}_2)_2(\text{C}_2\text{H}_3\text{O}_2)_6 \cdot 6\text{H}_2\text{O}$	847.4	701.1
$\text{Zn}(\text{UO}_2)_2(\text{C}_2\text{H}_3\text{O}_2)_6 \cdot 7\text{H}_2\text{O}$	845.1	707.7

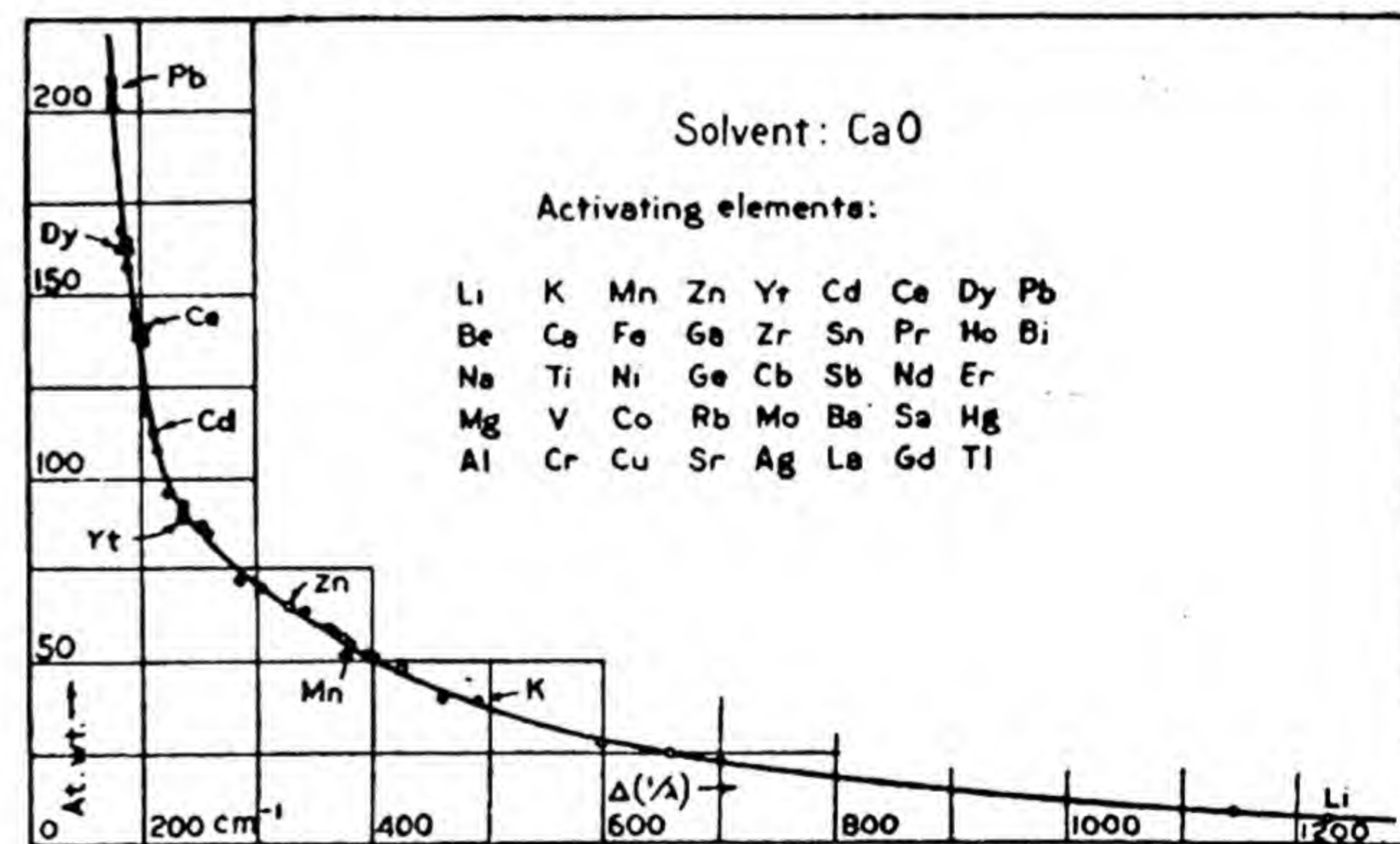


FIG. 2.—Mean frequency interval between bands of cathodoluminescence of solid solutions: Effect of atomic weight of activating element (34).

Elements in solid solution in  $\text{CaO}$ ; \* cathodoluminescence (34)

	Sets	$\Delta_l$		Sets	$\Delta_l$
Ag	2	212	Bi	1	146
Al	1	598		2	202
Ba	1	199	Ca	2	426
	2	203		2	512
Be	2	1145	Cb	1	215
				2	255

\*  $\text{CaCO}_3$  excited by Fe-spark (28),  $\text{CaO}$  excited by H-flame (12), and cathodoluminescence of  $\text{CaO}$  activated with Mn (34), all emit the same two series of bands characterized by  $\Delta_l = 420 \text{ cm}^{-1}$ ; see Fig. 2.



TABLE 7.—(Continued)

	Sets	$\Delta_i$		Sets	$\Delta_i$
Cd.....	1	187	Mo (Continued)	2	236
	2	226	Na.....	2	700
Ce.....	1	172	Nb.....	sec Cb	
	2	223	Nd.....	1	183
Co.....	2	322		2	201
	2	399	Ni.....	2	367
Cr.....	2	364	Pb.....	1	165
	2	423		2	185
Cu.....	2	340	Pr.....	1	170
Dy.....	2	182		2	218
Er.....	2	183	Rb.....	4	256
Fe.....	2	374	Sa.....	1	167
Ga.....	3	302		2	208
Gd.....	2	186	Sb.....	1	191
Ge.....	2	284		2	212
Gl.....	see Be		Sn.....	1	199
Hg.....	1	171		2	206
	2	180	Sr.....	2	225
Ho.....	1	186		2	275
K.....	2	465	Ti.....	2	424
	2	512	Tl.....	1	174
La.....	2	196	V.....	2	392
Li.....	1	1218		2	405
	2	1236	Yt.....	1	223
Mg.....	1	657		2	243
Mn.....	2	340	Zn.....	2	326
	2	420	Zr.....	1	227
Mo.....	2	209		2	242

## Other substances

Substance	Excited	Series	$\Delta_i$	Lit.
CaO.....	H-flame	1, 2	420	(12)
CaCO <sub>3</sub> .....	Fe-spark	1, 2	420	(25)
Cb <sub>2</sub> O <sub>5</sub> .....	H-flame	1, 2	210	(23)

TABLE 8.—VARIATION OF LUMINESCENCE WITH CONCENTRATION

$B$  = brightness;  $C = m/M$ ,  $m[M]$  = mass of substance [of solvent\*];  $\epsilon$  = too weak for measurement. For each mixture the excitation is same for all values of  $C$ . Unit of  $B$  is arbitrary.

Type	Cathodoluminescence			Fluorescence (38)		
Substance	Sm <sub>2</sub> O <sub>3</sub>	MnO	MnO*	Fluorescein, (C <sub>20</sub> H <sub>12</sub> O <sub>5</sub> )		
Solvent	CaO (6.1)	CaO (6.1)	Ca <sub>3</sub> (PO <sub>4</sub> ) <sub>2</sub> (6.2)	H <sub>2</sub> O with trace of NH <sub>4</sub> OH		
$C$	$B$			$C$	$B/C$	$10^4 B \uparrow$
0	1	0.5	0	$5 \times 10^{-9}$	21.8	0.001
0.00001	1	2	$\epsilon$	$1 \times 10^{-8}$	20.6	0.002
0.00010	2	4	$\epsilon$	$2 \times 10^{-8}$	18.7	0.004
0.00055	4	6	$\epsilon$	$4 \times 10^{-8}$	18.8	0.007
0.0010	6	9	8	$8 \times 10^{-8}$	17.1	0.014
0.0018	8		$\epsilon$	$16 \times 10^{-8}$	17.2	0.028
0.0020			16	$6 \times 10^{-8}$	17.2	1.0
0.0050			21	$12 \times 10^{-8}$	17.3	2.1
0.0055	10	10		$25 \times 10^{-8}$	15.7	3.9
0.010	9	9	20	$5 \times 10^{-8}$	14.3	7.2
0.013	8	8		$1 \times 10^{-4}$	10.2	10.2
0.03	7		$\epsilon$	$2 \times 10^{-4}$	4.39	8.8
0.05			$\epsilon$	$4 \times 10^{-4}$	1	4.0
0.06		6	$\epsilon$			
0.1		4	$\epsilon$			
0.3			0			
0.4	4	1	0			
1.0	0	0	0			

\* For the solvent Ca<sub>3</sub>(PO<sub>4</sub>)<sub>2</sub>,  $M$  is mass of the equivalent amount of CaO.  
 $\uparrow$  Computed from  $B/C$ , which is corrected for absorption and radiation other than that due to active molecules.

TABLE 9.—MISCELLANEOUS DATA

**Fatigue (14).**—Esculin (C<sub>15</sub>H<sub>16</sub>O<sub>9</sub>) in H<sub>2</sub>O, concentration = 4 in 100 000, continuous excitation by Hg-arc in SiO<sub>2</sub> tube, time ( $\tau$ ) measured from beginning of exposure, brightness ( $B$ ) in an arbitrary unit.

$\tau$ .....	0	3	6	10	15	21	25	31	41	55	min
$B$ .....	83	68	57	39	22	12	7	3	2	1	

If  $55 \geq \tau \geq 21$  min,  $B^{-0.5} = -0.15 + 0.021\tau$ .

**Decay of Luminescence (35).**—N at pressure = 0.22 mm of Hg, excitation by electrodeless discharge for 3.95 sec, time ( $\tau$ ) measured from end of excitation, brightness ( $B$ ) in an arbitrary unit.

$\tau$ .....	3.70	5.85	8.85	11.30	14.60	19.50	25.65	sec
$B$ .....	100	50	25	15	10	6	3.5	

For this range of  $\tau$ ,  $B^{-0.5} = +0.026 + 0.020\tau$ .

**Energy Emitted during Phosphorescence (10).**—ZnS activated by Cu, 1 g Cu to 10<sup>5</sup> g ZnS. Total light = 0.248 candle-second per cm<sup>2</sup>; total energy = 6680 erg = 22.5 kg-cal per g-atom of Cu = 0.42 quantum of radiation ( $\lambda = 5330 \text{ \AA}$ ) per atom of Cu.

**Efficiency of Chemiluminescence (1).**—N saturated with vapor of P at 25°C.  $B = 0.0215$  millilambert, efficiency = 1.1 lumen per kilowatt of energy emitted during the reaction.

**Effect of Pressure ( $p$ ) upon Luminescence of N (35).**—Excited by continuous electrodeless discharge; brightness ( $B$ ) in an arbitrary unit.

$p$ .....	0.080	0.106	0.144	0.192	0.257	0.323	0.440	mm
$B$ .....	63.3	173	364	902	2 200	4 576	20 400	

$B = 129\,000p^3$ .

**Variation of Fluorescence with Depth.**—Owing to absorption, the intensity of the active constituents of the exciting radiation progressively decreases as the radiation penetrates the substance; the brightness ( $B_z$ ) of the fluorescence excited in the layer at depth  $z$ , likewise decreases. The values of  $B_z$  for (a) uranium glass, (b) quinine sulfate (C<sub>20</sub>H<sub>16</sub>N<sub>4</sub>O<sub>6</sub>S) in H<sub>2</sub>O with trace of HNO<sub>3</sub>, and (c) fluorescein (C<sub>20</sub>H<sub>12</sub>O<sub>5</sub>) in H<sub>2</sub>O with trace of NaOH are as follows (11):

Unit of  $z = 1$  mm; of  $B_z$  is arbitrary

$z$	a	b	c
0	4.60	4.20	1.72
1	3.31	2.88	1.11
2	2.24	2.04	0.54
3	1.70	1.59	0.34
4	1.37	1.10	0.17
5	1.14	0.76	0.12
6	0.95		
7	0.60		
8	0.48		
9	0.36		

Within about  $\pm 10\%$  these can be represented by the expression  $B_z = B_0 e^{-\mu z}$  where  $\mu_a = 0.28$ ,  $\mu_b = 0.34$ ,  $\mu_c = 0.56$ . The value of  $\mu$  will vary with the concentration.

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## FLUORESCENCE OF GASES

C. D. CHILD

There are several distinct types of fluorescence in gases:

1. The simplest type is an atomic phenomenon in which the emitted radiation has the same frequency as the exciting light (8, 18, 50, 53). This has been called resonance radiation. The following table shows the wave-lengths ( $\lambda$ ) which have been used to excite such radiation in various vapors (unit of  $\lambda = 1 \text{ \AA}$ ).

Vapor	$\lambda$	Lit.
Bi.....	2277, 3068	(42, 57)
Cd.....	2289, 3262	(22, 43)
Hg.....	1849, 2537	(3, 12, 16, 19, 21, 39, 40, 41, 51, 61, 64, 71)
Li.....	6708	(1)
Na.....	3303, 5890, 5896	(56, 60, 66)
Pb.....	2833	(42, 57)
Tl.....	2768, 3776	(28, 42, 57)
Zn.....	2139, 3075	(52, 59)

2. In some cases an atomic vapor will emit certain lines of its arc spectrum of wave-lengths different from those of the exciting light (14, 42, 57). Such lines are said to be optically excited.

Many of the mercury lines have been excited in this manner and also  $\lambda_{Bi} = 4723$ ;  $\lambda_{Pb} = 3640, 4058$ ;  $\lambda_{Tl} = 5351, 3530 \text{ \AA}$ .

3. In a third type, which is a molecular phenomenon, a spectrum of 20 to 40 lines is emitted, one line being of the same frequency as that of the exciting radiation, one to three lines being of higher, and the remainder of lower frequency (6, 23, 25, 27, 30, 32, 33, 34, 36, 38, 47, 56, 62, 68, 69). Such spectra are called resonance spectra. In the vapors of I, Na and K they have been excited by a great number of wave-lengths.

4. In a fourth type there is no simple relation between the emitted and the exciting radiation (7, 9, 26, 31, 35, 37, 42, 46, 54, 57). In this type the emitted spectrum usually consists of many lines, in some cases it contains bands, and with Hg-vapor at pressure of 0.45 mm Hg it seems to be continuous from the yellow to 3000  $\text{\AA}$ . This type has been observed with many pure gases, and with the vapors of Hg, I, K and Na when they are mixed with other gases. In some cases the exciting radiation may be changed through wide limits without producing any change in the character of the emitted radiation.

**Polarization** (5, 17, 20, 32, 33, 44).—In the absence of a magnetic field, the radiation in types 1 and 3 is generally polarized in the same direction as the exciting light. The amount of polarization depends upon the gas and upon many external conditions, and in some cases is greatly affected by a weak magnetic field.

The radiation in type 4 has never been found to be polarized.

**Effect of Magnetic Fields** (2, 10, 11, 15, 24, 49, 55, 58, 67, 70).—Magnetic fields are known to affect the polarization and intensity

of the radiation in type 1, and the intensity in type 3. The effect on type 1 varies with the direction of emission, and depends on the direction of the field with respect to the direction and plane of polarization of the incident light. In this respect resonance radiation is very sensitive, responding markedly to a field strength of one gauss in the case of Hg2537, and to a field strength of less than 100 gauss for the D lines of sodium.

Observations on type 3 have shown that, at least in the case of iodine vapor, the fluorescence is practically extinguished in fields stronger than 30 000 gauss.

General discussion of fluorescence of gases (4, 45, 63).

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SPECTRAL SERIES OF THE ELEMENTS<sup>1</sup>

H. M. HANSEN AND V. THORSEN

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## INTRODUCTION

**Spectral Series.**—In most line spectra there have been found certain groups of lines which are distributed in a regular manner. Each of these groups is called a spectral series. In any series the wave number ( $1/\lambda$ ) of every line can be written as a difference between two spectral terms ( $1/\lambda = T_1 - T_2$ )—combination principle of Rydberg-Ritz (76, 234). Throughout this report  $\lambda$  is the wave-length of the line in a vacuum. For each spectrum, the terms ( $T$ ), which are much less numerous than the lines, can be arranged in sequences characteristic of the element producing it. On Bohr's theory,  $h\nu (=hc/\lambda) = E_2 - E_1$ , where  $E_2$  and  $E_1$  denote the energy of the emitting atom in two "stationary" states; on this theory, except for an additive constant,  $T_1 = -E_1/hc$ ,  $T_2 = -E_2/hc$ . Hence the spectral terms are often called energy levels of the atom.

If we neglect the "fine structure" of the lines, atoms containing only one electron external to the nucleus (H, He<sup>+</sup>, etc.) emit spectra having only one series of terms;  $T_H = N_H/m^2$ ,  $T_{He^+} = 4N_{He}/m^2$ , where  $N_H = 109\,677.7\text{ cm}^{-1}$ ,  $N_{He} = 109\,722.1\text{ cm}^{-1}$ ,  $m = 1, 2, 3, \dots, \infty$ .  $N$  is called the Rydberg constant, or wave-number, and on Bohr's theory its value for an atom of mass  $M$  is  $N_M = 2\pi^2 m_0 e^4 h^{-3} c^{-1} M/(M + m_0) = N_\infty M/(M + m_0)$ . The best available values for  $N_H$  are  $109\,677.7 \pm 0.2$  (16) and  $109\,677.26 \pm 0.23$  (246); the former is used by Paschen (228) and others, and is accepted for this report. Taking  $M_H/m_0 = 1847$  (cf. Vol. 1, p. 18), this gives  $N_M = 109\,677.7 + 59.37 \left(1 - \frac{1}{\text{At. wt.}}\right)$  approx. and  $N_\infty = 109\,737.1$ ; the latter differs notably from the value derived from the fundamental constants accepted for the I. C. T. (cf. Vol. I, p. 17, 18), the difference arising from slight errors in the accepted values for  $e$ ,  $h$ , and  $e/m_0$ , especially the latter.

If the atom contains more than one external electron, there is more than one sequence of terms. The different sequences are generally designated by the letters  $s, p, d, f, \dots$ , and the general terms by  $ms, mp, \dots$  (sometimes by  $(m, s), (m, p), \dots$ ) where  $m$  is an integer. In the simplest case the general scheme is as shown in (1)

1s	2s	3s	4s	5s	...	ms	...
	2p	3p	4p	5p	...	mp	...
		3d	4d	5d	...	md	...
			4f	5f	...	mf	...
				5g	...	mg	...
					...	mh	...

(1)

In each sequence the value of the term approaches zero with increasing  $m$  and often can approximately be represented by  $N_M/(m + \alpha)^2$ , where  $\alpha$  is a constant. For closer approximations,

<sup>1</sup> This section contains data and bibliography to March, 1928, but the report was originally prepared in 1925 and it has been impossible to change the notation and the arrangement of the tables so as to make them accord with the more recent theoretical work (see (125)). The numerous, more or less isolated, sets of multiplets which have been discovered are included by literature reference only. All additions to the 1925 report have been made by V. Thorsen, who also took part in the preparation of that report.

see (76); cf. (90). In most spectra the  $p$ -terms,  $d$ -terms, ... are multiple, being divisible into 2 or more sequences, denoted as  $mp_1, mp_2, \dots, md_1, md_2, \dots$ . In many spectra 2 or more such systems of multiple-term sequences with different multiplicities occur, the different systems in any spectrum exhibiting either all even or all odd multiplicity. In several spectra there is in addition a distinctly different scheme of terms in which the members of a sequence are approximately represented by the expression  $A + \frac{N_M}{(m + \alpha)^2}$ . These terms are called anomalous, displaced, or primed terms.

**Permissible Lines.**—When more than one sequence of terms exists, we do not find lines corresponding to the differences of all possible pairs of terms, but only of certain particular pairs. For the simplest case, scheme 1, lines are rarely found except for the cases indicated in Table 1; these correspond to "permissible" lines.

TABLE 1.—TERM DIFFERENCES CORRESPONDING TO PERMISSIBLE LINES

Series	$1/\lambda^*$	$m$	$1/\lambda$	$m$	$1/\lambda$	$m_1$	$m_2$
Principal.....	1s-mp	>1	2s-mp	>2	$m_1s-m_2p$	>0	> $m_1$
1st subordinate†.....	2p-md	>2	3p-md	>3	$m_1p-m_2d$	>1	> $m_1$
Fundamental‡.....	3d-mf	>3	4d-mf	>4	$m_1d-m_2f$	>2	> $m_1$
	etc.		etc.		etc.		
2nd subordinate§.....	2p-ms	>1	3p-ms	>2	$m_1p-m_2s$	>1	$\leq m_1$
	3d-mp	>2	4d-mp	>3	$m_1d-m_2p$	>2	$\leq m_1$
	4f-md	>3	5f-md	>4	$m_1f-m_2d$	>3	$\leq m_1$
	etc.		etc.		etc.		

\* Generally the strongest of the series. † Bergmann series.

‡ Diffuse subordinate series.

§ Sharp subordinate series.

There are similar limitations upon the line-producing differences between the components of multiple terms, as between  $p_i$  and  $d_i$ , and between terms belonging to different systems of sequences.

The general features of series spectra may be interpreted on Bohr's theory by assuming that in each of the several stationary states involved in the emission of the lines of a series, one electron, the so-called series electron, is moving in an orbit which is large as compared with those of the other electrons, and which differs from state to state, and that this electron has a general central motion; i.e., it has a plane periodic motion on which is superposed a rotation of the orbit in the plane, the plane itself performing a uniform precession around an invariable axis fixed in the atom. For such a motion, the stationary states are characterized by 3 quantum numbers,  $n, k, j$ . The main quantum number  $n$  is correlated with the period of revolution of the electron,  $k$  with the rotation of the orbit in its plane, and  $j$  with the precession of the orbital plane. We may write: Angular momentum of electron in plane of orbit =  $kh/2\pi$ ; total angular momentum of electron =  $j\hbar/2\pi$ . For this type of motion,  $n$  may change by any integral number at any transition, but the correspondence principle restricts the actual transitions to such as correspond to a change of  $k$  by one unit and of  $j$  by either one or no unit. This interprets the empirically discovered selection rules of Table 1 if  $k = 1$  for the  $s$ -sequence, 2 for the  $p$ -, 3 for the  $d$ -, etc. It also interprets the observed restrictions in the intercombination of the multiple terms if to each component of a multiple term is ascribed a certain value of  $j$ . The anomalous or primed terms are interpreted as arising from the simultaneous excitation of more than one electron. It is possible to assign to these terms such quantum numbers  $k$  and  $j$  that the selection rules governing pairs of primed terms are the same as those for ordinary terms; but those governing combinations involving a primed and an ordinary term, which are characterized by



special Zeeman patterns, differ, in that  $k$  must remain unchanged or must change by two units. On this theory, the capricious appearance of lines corresponding to combinations that do not satisfy these rules is ascribed to the perturbing influence of external forces (20).

The simple model considered in this theory does not offer a sufficient basis for the interpretation of the multiplicity of the terms, the separation of the components of the multiplets, the laws of their anomalous Zeeman effect, and other fine details. Hence it is difficult to assign definite, absolute values to the quantum numbers corresponding to each term. This is especially true of  $j$ , for which there is at present no generally accepted assignment; but if the  $j$ -value for one sequence is fixed, it is possible in all other sequences of the same spectrum to fix uniquely the  $j$ -value in such a way that the only combinations giving permissible lines are those corresponding to the restrictions already mentioned. The values proposed by Sommerfeld (295, 298) for spectra of the simplest types are shown in Fig. 1, where the permissible combinations are shown by connecting lines; in combinations between systems of different multiplicities, that in which  $j$  remains unaltered and  $= 0$  is not permissible.

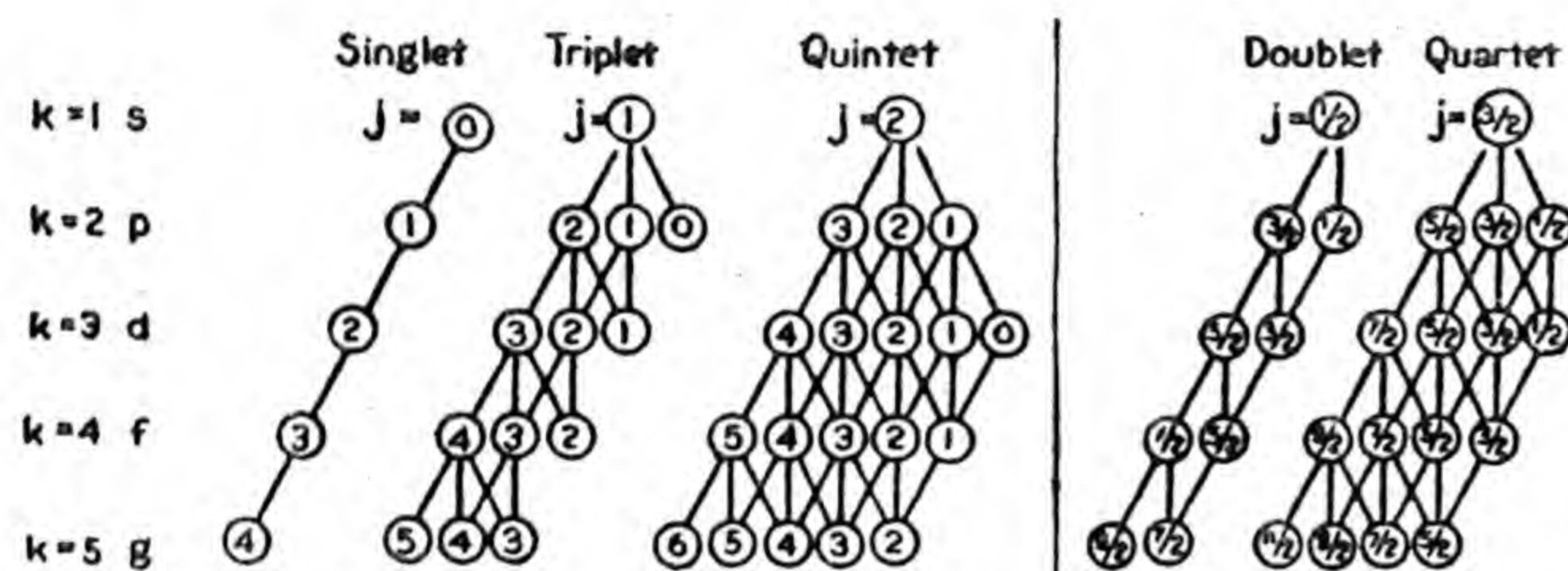


FIG. 1.

**Notation Used in This Report.**—In view of the uncertainties mentioned, we have refrained from basing the term notation entirely upon the quantum symbols. As the theory is incomplete, we take no account of the theoretical values of  $n$ , now used as serial number by Paschen (233), but in general we follow the notation hitherto used by him (234):

1. The serial number of the terms is in accordance with scheme (1) (Ritz-notation), the number 1 being used for the first  $s$ -term, 2 for the first  $p$ -term, etc. But if the normal state of the atom is not an  $s$ -state or if the first  $s$ -term is not the largest term in the system, the first  $s$ -term is called  $2s$ . (2) The letter notation of the sequences is in accordance with scheme (1); if there are two systems, capitals are used for sequences of lower multiplicity; in other cases small letters are used. (3) Components of multiple terms are denoted by numerical subscripts, as  $p_1, p_2, p_3$ . The subscript 1 is assigned to that term which, from the combination rules and the relative intensities, is inferred to correspond to the highest value of  $j$ ; this term is the smallest in the ordinary and the largest in the inverse type of system. (4) The so-called anomalous, displaced, or accented terms giving sequences of the type  $A + \frac{N_M}{(m + \alpha)^2}$  are denoted by primes, etc. ( $p', p'', \dots$ ). Primes,  $\dots$  are also used for distinguishing the several components of the multiple sets of multiple terms occurring in the systems of Cr, Mo, and Mn. (5) The spectrum of a multiply ionized atom is indicated by placing after the chemical symbol a Roman numeral denoting the multiplicity of the ionization; thus, Si I, Si II, Si III, Si IV.

**Other Notations.**—(1) *Serial Number.*—In his later work, Paschen (233) uses the theoretical value of  $n$  as the serial number, but the theory is incomplete. Fowler uses that value of  $m$  which

makes  $\alpha < 1$  or nearly  $= 1$  in the expression  $N_M/(m + \alpha)^2$ ; in most spectra this requires our  $2p$  term to be called  $1p$ , our  $3d$  term to be called sometimes  $2d$  and sometimes  $1d$ , etc.

2. *Sequence Notation.*—Fowler uses Greek letters  $\sigma, \pi, \delta, \varphi$ , for the doublet system. Our  $f$ -terms are denoted by  $b$  by Hansen, Takamine, and Werner (115) and some others, and by  $\Delta$  by Roshdestvenskii (245). Series beyond our  $f$  were formerly denoted by  $N/5^2, N/6^2, \dots$ ; Paschen and Fowler now denote them by  $f', f'', \dots$ , Roshdestvenskii by  $\Delta^1, \Delta^2, \dots$ , Hansen, Takamine, and Werner (115) by  $e, f, g, \dots$ .

3. *Components of Multiple Terms.*—Fowler now uses the notation of this report, but formerly, while using that for the  $p$ -terms, he used  $d, d', d'', \dots$  for the  $d$ -terms. Sommerfeld proposes the use of subscripts having the values of  $j$  if the multiplicity is odd, and of  $(j + \frac{1}{2})$  if multiplicity is even. In the simplest cases the correspondence between the Sommerfeld notation and that here used is as shown below:

Notation	Doublets			Triplets		
Here used	$p_1$	$p_2$	$p_3$	$d_1$	$d_2$	$d_3$
Sommerfeld	$p_2$	$p_1$	$p_0$	$d_3$	$d_2$	$d_1$

4. *Russell and Saunders' Notation* (257).—Russell and Saunders propose that the general term be represented by  $m'D_i$ . For the serial number  $m$  they provisionally take the values used by Fowler; capitals replace the small letters in scheme (1), and thus indicate the value of  $k$ ;  $r$  denotes the multiplicity of the term; and  $i$  indicates the component of the multiple term; it is intended to be the integral value of  $j$  or of  $(j + \frac{1}{2})$ . The index  $r$  may be omitted if term is a singlet, and  $i$  may be omitted if it is a singlet or an unresolved multiplet.

TABLE 2.—TERM VALUES FOR SPECTRAL SERIES

Term values are calculated from wave-lengths expressed in the international scale and reduced to vacuum (by tables of Bureau of Standards (199)). Only terms calculated from observed lines are given. Value of  $n$  for first term in each sequence is printed in bold face, if known; value of  $k$  is indicated by term symbol (for  $s$ ,  $k = 1$ ;  $p$ ,  $k = 2$ ; etc.), and of  $j$  by lower index of the Russell-Saunders' notation (given in parentheses)—the index  $= j$  if the multiplicity is odd,  $= j + \frac{1}{2}$  if even. For terms greater than  $1000 \text{ cm}^{-1}$  the "effective" quantum number ( $n^*$ ) is given in italics ( $n^{*2} = r^2 N_M / T$  where  $T$  = term value and  $(r - 1)$  = degree of ionization); errors in  $n^*$  may amount to 0.001. For wave-lengths used, see (76, 119, 233, 234)† and references mentioned in the table. Graphical representations, see (21). ( ) indicates value is uncertain; int. = international;  $\delta$  = uncertainty in term value;  $n, k, j$  = quantum numbers,  $N$  = Rydberg constant, based on  $N_\infty = 109\,737.1$ ; series notation, see p. 392. Unit of  $T, \delta$ , and  $N = 1 \text{ cm}^{-1}$  if 1 int. Å =  $10^{-8} \text{ cm}$ .

A Z = 18.  $N_A = 109\,735.6$ .

A I (204, 205, 206, 272, 273).

A III (124).

Ag Z = 47.  $N_{Ag} = 109\,736.5$ .

Ag I (129, 239, 243, 283). Limits (76).

$m$	1	2	3	4	5	6
$ms (m^2S_1)$	61 095.9	18 540.0	9 209.0	5 516.2	3 676.6	2 606.5
$n; n^*$	<b>5</b> ; 1.330	2.433	3.461	4.461	5.539	6.489
$mp_1 (m^2P_1)$		31 543.6	12 798.7†			
$n; n^*$		<b>5</b> ; 1.865	2.981			
$mp_1 (m^2P_1)$		30 623.0	12 595.8†			
$n; n^*$		<b>5</b> ; 1.893	2.951			

† In (76) new series formulae have been calculated,  $\lambda$  is expressed in int. Å but  $N_H$  is used for all elements; in (233, 234) most  $\lambda$ 's are on Rowland's scale; in (233) it is not stated whether term values are based on int. Å or Rowland's scale, and in some instances the scale is not the same for all sequences of the same element.

‡ Calculated from ( $p, p$ ) combinations; confirmed by observations (283).



Ag I.—(Continued)

m	1	2	3	4	5	6
$md_2$ ( $m^2D_2$ )			12 351.6	6 891.4	4 394.3	3 040.2
n; n*			5; 2.981	3.990	4.997	6.008
$md_1$ ( $m^2D_1$ )			12 331.3	6 880.7	4 388.6	3 035.9
n; n*			5; 2.983	3.994	5.001	6.012
$mf$ ( $m^2F$ )				6 891.3	4 386.2	
n; n*				4; 3.990	5.002	
m	7	8	m	7	8	9
$ms$ ( $m^2S_1$ )	1 957.5	1 526.6	$md_1$ ( $m^2D_1$ )	2 224.8	1 698.3	1 337.3
n*	7.488	8.478	n*	7.024	8.039	9.059

Ag II (9, 184).

Al Z = 13.  $N_{Al} = 109 734.9$ .

Al I (130, 202, 222). Limits (76).

m	2	3	4	5	6
$ms$ ( $m^2S_1$ )	22 933.3	10 591.6	6 136.8	4 007.7	2 833.2
n; n*	4; 2.187	3.219	4.228	5.233	6.223
$mp_2$ ( $m^2P_1$ )	48 280.9	15 331.7	8 009.2	4 946.0	3 352.6
n; n*	3; 1.508	2.675	3.702	4.710	5.722
$mp_1$ ( $m^2P_2$ )	48 168.8	15 316.5	8 003.2	4 943.2	3 350.6
n; n*	3; 1.509	2.677	3.703	4.711	5.724
$md_2$ ( $m^2D_2$ )		15 845.5	9 351.7	6 047.4	4 114.3
n; n*		3; 2.631	3.426	4.260	5.165
$md_1$ ( $m^2D_1$ )		15 844.2	9 347.2	6 043.3	4 112.1
n; n*		3; 2.631	3.427	4.261	5.166
$mf$ ( $m^2F$ )			6 962.3	4 451.2	3 087.7
n; n*			4; 3.970	4.965	5.961
m	7	8	9	10	11
$md_2$ ( $m^2D_2$ )	2 936.0	2 187.1	1 684.6	1 338.6	1 088.9
n*	6.113	7.084	8.071	9.055	10.039
$md_1$ ( $m^2D_1$ )	2 935.1	2 185.7	1 684.3	1 336.9	1 091.0
n*	6.114	7.086	8.071	9.060	10.029

Al II. Terms: singlet ( $2^78$ ); cf. ( $2^53$ ), triplet ( $2^32$ ). Spectrum is analogous to that of Mg I.

Singlet system.

m	1	2	3	4	5	6
$ms$ ( $m^1S_0$ )	151 860.4	56 512.0	35 495.2	19 084.0	13 061.1	9 499.6
n; n*	3; 1.700	2.787	3.794	4.796	5.797	6.798
$mp$ ( $m^1P_1$ )		92 010.7	44 942.2	25 993.7	16 943.1	11 943.7
n; n*		3; 2.184	3.125	4.109	5.090	6.062
$md$ ( $m^1D_2$ )			66 381.4	41 772.9	27 068.4	17 946.3
n; n*			3; 2.571	3.242	4.027	4.946
$mf$ ( $m^1F_3$ )				28 392.3	18 177.0	12 617.5
n; n*				4; 3.932	4.914	5.898
m	7	8	9	10	11	12
$ms$ ( $m^1S_0$ )	7 218.5	5 670.3	4 571.6	3 763.3	3 153.5	2 680.6
n*	7.798	8.798	9.779			
$mp$ ( $m^1P_1$ )	8 901.5	6 921.3	5 562.9	4 591.6	3 858.4	3 281.0
n*	7.022	7.964	8.883	9.777		
$md$ ( $m^1D_2$ )	12 573.6	9 253.4	7 080.2	5 586.0	4 517.2	3 727.7
n*	6.908	6.887	7.874	8.865	9.856	
$mf$ ( $m^1F_3$ )	9 258.8	7 078.5	5 583.9	4 516.2	3 727.8	3 128.8
n*	6.885	7.875	8.866	9.859		
m	13	14	15	16	17	18
$ms$ ( $m^1S_0$ )	2 305.7	2 003.8				
$mp$ ( $m^1P_1$ )	2 808.5	2 425.6	2 112.4	1 852.8		
$mf$ ( $m^1F_3$ )	2 661.2	2 291.8	1 994.2	1 750.7	1 549.3	1 380.7†

†  $19^1P_1 = 1 238.2$ ;  $20^1P_1 = 1 116.3$ .

Triplet system

m	2	3	4	5	6	7
$ms$ ( $m^3S_1$ )	60 589.2	31 770.6	19 648.0	13 363.7	9 680.6	7 336.1
n; n*	4; 2.692	3.716	4.728	5.732	6.734	7.736
$mp_2$ ( $m^3P_0$ )	114 468.4	46 436.1	26 159.9	16 851.4		
n; n*	3; 1.958	3.075	4.096	5.104		
$mp_1$ ( $m^3P_1$ )	114 406.6	46 422.0	26 154.2	16 848.3		
n; n*	3; 1.959	3.075	4.096	5.105		
$mp_1$ ( $m^3P_2$ )	114 281.1	46 392.7	26 141.4	16 841.5	11 767.4	8 680.8
n; n*	3; 1.960	3.076	4.098	5.106	6.107	7.111
$md_2$ ( $m^3D_1$ )†		56 311.6	30 379.2			
n; n*		3; 2.792	3.801			
$md_2$ ( $m^3D_2$ )†		56 312.5	30 379.5			
n; n*		3; 2.792	3.801			
$md_1$ ( $m^3D_3$ )†		56 313.6	30 380.1	19 040.7	13 048.5	9 497.6
n; n*		3; 2.792	3.801	4.802	5.800	6.798

Al II. Triplet system.—(Continued)

m	2	3	4	5	6	7
$mf_2$ ( $m^3F_2$ )			28 444.5†	18 425.4	13 341.7	10 778.0
n; n*			4; 3.928	4.881	5.737	6.589
$mf_2$ ( $m^3F_3$ )			28 442.4†	18 420.0	13 324.0	10 752.9
n; n*			4; 3.928	4.881	5.740	6.589
$mf_1$ ( $m^3F_4$ )			28 439.6†	18 413.1	13 301.2	10 719.9
n; n*			4; 3.928	4.882	5.745	6.599
$mf$ (?)‡			28 392.3†			
n; n*			4; 3.932			
$mg$ ( $m^3G$ )					12 271.7	9 011.2
n; n*					6; 5.981	6.979

m	8	9	10	11	12	13
$ms$ ( $m^3S_1$ )	5 751.6	4 631.4	3 807.9	3 188.4		
n*	8.733	9.734				
$md_1$ ( $m^3D_1$ )†	7 221.5	5 675.4	4 577.6	3 770.4		
n*	7.796	8.794	9.792			
$mf_2$ ( $m^3F_2$ )	8 597.7	6 733.9	5 363.7	4 360.6	3 611.7	
n*	7.145	8.074	9.047	10.034		
$mf_2$ ( $m^3F_3$ )	8 590.6	6 731.5	5 362.6	4 360.2	3 611.3	
n*	7.148	8.076	9.048	10.034		
$mf_1$ ( $m^3F_4$ )	8 579.8	6 728.3	5 361.2	4 359.6	3 610.8	3 037.9
n*	7.153	8.077	9.049	10.034		
$mg$ ( $m^3G$ )	6 895.7	5 445.9	4 409.4	3 642.8	3 060.0	
n*	7.978	8.978	9.977			

m	14	15	16	18
$mf_1$ ( $m^3F_4$ )	2 590.9	2 234.9	1 947.2	1 516.9

† d-terms are inverse.

‡ 4f-terms are double; unusual in triplet systems.  $\Delta 4f_1 = 0.254$ ,  $\Delta 4f_2 = 0.490$ .  $\Delta 4f_1 = 0.100$ ,  $\Delta 4f = 0.489$ .

§ Position of this term is not clear. Paschen denoted it by F.

Al III (171, 231). Spectrum analogous to that of Na I; d-terms are inverse.

m	1	2	3	4	5	6
$ms$ ( $m^3S_1$ )	229 454.0	103 291.4	58 816.0	37 952.0		
n; n*	3; 2.074	3.092	4.098	5.103		
$mp_2$ ( $m^3P_1$ )		175 774.1	85 821.7	51 023.5	33 797.6	
n; n*		3; 2.370	3.392	4.399	5.406	
$mp_1$ ( $m^3P_2$ )		175 536.1	85 741.6	50 984.4		
n; n*		3; 2.372	3.394	4.403		
$md_2$ ( $m^3D_2$ )			113 496.7	63 667.5		
n; n*			3; 2.950	3.938		
$md_1$ ( $m^3D_1$ )			113 499.0	63 668.7	40 578.5	28 079.6
n; n*			3; 2.950	3.938	4.933	5.931
$mf_2$ ( $m^3F_2$ )				61 841.9	39 578.7	
n; n*				4; 3.996	4.995	
$mf_1$ ( $m^3F_4$ )				61 841.6	39 578.5	27 484.5
n; n*				4; 3.996	4.995	5.995
$mg$ ( $m^3G$ )					39 526.2	27 452.7
n; n*					5; 4.998	5.998
$mh$ ( $m^3H$ )						27 446.7
n; n*						6; 5.998
m	7	8	m	7	8	9
$md_1$ ( $m^3D_1$ )	20 573.6	15 712.6	$mg$ ( $m^3G$ )	20 171.8	15 443.3	
n*	6.929	7.928	n*	6.997	7.997	
$mf_1$ ( $m^3F_4$ )	20 193.0	15 461.9	$mh$ ( $m^3H$ )	20 166.5	15 438.2	12 198.8
n*	6.994	7.993	n*	6.998	7.998	8.998

As Z = 33.  $N_{As} = 109 736.3$  (248).Au Z = 79.  $N_{Au} = 109 736.8$ .

Au I (173, 174, 309). Hicks (118) gives a different arrangement.

m	1	2	3	4	5	6
$ms$ ( $m^3S_1$ )	74 407.6	19 922.7	9 665.1	5 728.2	3 790.9	2 662.9
n; n*	6; 1.215	2.347	3.369	4.377	5.380	6.419
$mp_2$ ( $m^3P_1$ )		37 048.8				
n; n*		6; 1.721				
$mp_1$ ( $m^3P_2$ )		33 233.4				
n; n*		6; 1.818				
$md_2$ ( $m^3D_2$ )			12 455.5	6 938.5	4 437.9	3 053.1†
n; n*			6; 2.969	3.977	4.973	5.995
$md_1$ ( $m^3D_1$ )			12 373.7	6 895.6	4 398.3	3 015.1†
n; n*			6; 2.978	3.989	4.995	5.933

† For m = 7,  $md_2 = 2 240.5$ ,  $n^* = 6.998$  and  $md_1 = 2 206.1$ ,  $n^* = 7.053$ .



B Z = 5.  $N_B = 109\,731.6$ .

B I (22, 279); cf. (25, 44). Terms (275).

m	2	3	m	3	4	5
$ms (m^2S_1)$	27 043	12 075	$md (m^2D)$	12 315	7 084	4 594
n; n*	2; 2.014	3.015	n; n*	2; 2.985	3.936	4.886
$mp_1 (m^2P_1)$	67 082					
n; n*	2; 1.879					
$mp_1 (m^2P_2)$	67 067					
n; n*	2; 1.879					

B II (279). Terms (28).

Singlet system

m	1	2	m	2	m	3
$mS (m^1S_0)$	194 325.9	66 665.1	$mP (m^1P_1)$	120 929.4	$mD (m^1D_2)$	48 410.3
n; n*	2; 1.504	2.566	n; n*	2; 1.906	n; n*	2; 3.011

Triplet system

m	2	3	m	3	4	5
$ms (m^2S_1)$	72 930.8	36 655.5	$md (m^2D)$	52 054.2	28 640.4	
n; n*	2; 2.453	3.461	n; n*	2; 2.904	3.914	
$mp_1 (m^2P_0)$			$mf (m^2F)$			17 795.7
$mp_1 (m^2P_1)$	165 362.7	59 010.0	n; n*			4; 4.967
n; n*	2; 1.629	2.727				
$mp_1 (m^2P_2)$	165 343.9	59 006.5				
n; n*	2; 1.629	2.727				

B III (25).  $\delta = \pm 5$ . Spectrum analogous to that of Li I.

m	1	2	m	3	4	5
$ms (m^2S_1)$	305 938	125 736	$md (m^2D)$	109 870		
n; n*	2; 1.797	2.805	n; n*	2; 2.998		
$mp_1 (m^2P_1)$		257 579	$mf (m^2F)$		61 742	
n; n*		2; 1.958	n; n*		4; 3.999	
$mp_1 (m^2P_2)$		257 545	$mg (m^2G)$			39 515
n; n*		2; 1.958	n; n*			5; 5.000

Ba Z = 56.  $N_{Ba} = 109\,736.7$ .

Ba I (239, 266, 267). Terms: normal (269), anomalous (257).

Singlet system

m	1	2	3	4	5	6
$mS (m^1S_0)$	42 029.4	16 399.6				
n; n*	6; 1.615	2.587				
$mP (m^1P_1)$		23 969.2	9 482.2	5 039.5	3 529.9	2 721
n; n*		6; 2.139	3.402	4.667	5.575	6.360
$mD (m^1D_2)$			30 634.1	13 800.4	7 931.5	4 988.3
n; n*			5; 1.893	2.820	3.720	4.690
$mP (m^1P_2)$				13 475.2	6 136.7	4 254.4
n; n*				4; 2.854	4.228	5.079

m	7	8	m	7	8
$mP (m^1P_1)$	2 044	1 606	$mD (m^1D_2)$	3 473.2	2 532.5
n*	7.327	8.266	n*	5.620	6.583

Triplet system, normal terms

m	2	3	4	5	6	7
$ms (m^2S_1)$	15 869.3	8 124.3	4 934.0	3 366.5	2 404.5	
n; n*	2; 2.629	3.676	4.716	5.710	6.758	
$mp_1 (m^2P_0)$	29 763.3	11 286.4	6 186.9			
n; n*	2; 1.924	3.118	4.211			
$mp_1 (m^2P_1)$	29 392.8	11 214.2	6 137.3			
n; n*	2; 1.935	3.128	4.228			
$mp_1 (m^2P_2)$	28 514.8	11 042.3	6 057.2			
n; n*	2; 1.961	3.152	4.256			
$md_1 (m^2D_1)$		32 995.6	11 333.9	6 320.1	4 067.5	2 888.7
n; n*		2; 1.824	3.111	4.167	5.194	6.168
$md_1 (m^2D_2)$		32 814.1	11 279.0	6 267.3	4 055.4	2 871.4
n; n*		2; 1.829	3.119	4.184	5.202	6.181
$md_1 (m^2D_3)$		32 433.0	11 211.6	6 244.2	4 041.0	2 843.8
n; n*		2; 1.840	3.128	4.192	5.210	6.212
$mf_1 (m^2F_1)$			7 426.8	4 634.6	3 213.8	2 351.2
n; n*			4; 3.845	4.866	5.844	6.832
$mf_1 (m^2F_2)$			7 412.8	4 610.4	3 210.1	2 348.7
n; n*			4; 3.847	4.879	5.847	6.835
$mf_1 (m^2F_3)$			7 398.6	4 505.3	3 204.2	2 346.3
n; n*			4; 3.851	4.895	5.852	6.839

Ba I. Triplet system, normal terms.—(Continued)

m	8	9	10	11	12	13
$md_1 (m^2D_1)$	2 137.1					
n*	7.166					
$md_1 (m^2D_2)$	2 134.8	1 649.1				
n*	7.170	8.157				
$md_1 (m^2D_3)$	2 124.2	1 646.8				
n*	7.171	8.164				
$mf_1 (m^2F_1)$	1 790.5	1 415.4	1 134.2	932.2		
n*	7.829	8.805	9.836			
$mf_1 (m^2F_2)$	1 788.0	1 407.8	1 132.8	932.9	782.6	665.2
n*	7.834	8.829	9.842			
$mf_1 (m^2F_3)$	1 785.2	1 401.6	1 132.2	933.0	781.9	664.7†
n*	7.840	8.849	9.844			

†  $14f_1 = 572.4$ ,  $15f_1 = 499$ .

Triplet system, anomalous terms

m	2	3
$mp_1' (m^2P_0')$	18 820.3	7 535.6
$mp_1' (m^2P_1')$	18 549.3	7 205.9
$mp_1' (m^2P_2')$	18 110.5	6 412.8

Ba II (165, 244). Term values calculated from data (76) and 4f-limit (90); corrected to int. scale. Spectrum analogous to that of Cs I.

m	1	2	3	4	5	6
$ms (m^2S_1)$	80 655.4	38 300.4	22 630.3	14 973	10 704	
n; n*	2; 2.333	3.403	4.404	5.415	6.404	
$mp_1 (m^2P_1)$		60 393.9				
n; n*		2; 2.696				
$mp_1 (m^2P_2)$		58 703.0				
n; n*		2; 2.734				
$md_1 (m^2D_1)$			75 781.7†	34 706.0	20 856.3	13 981.5
n; n*			2; 2.407	3.557	4.588	5.603
$md_1 (m^2D_2)$			74 980.6†	34 500.7	20 760.8	13 928.1
n; n*			2; 2.419	3.567	4.598	5.613
$mf_1 (m^2F_1)†$				32 396.3	21 714	16 184
n; n*				4; 3.681	4.495	5.209
$mf_1 (m^2F_2)†$				32 171.8	21 482	15 960
n; n*				4; 3.694	4.521	5.244

† Suggested changes (234, 237) have been made in the values of the 3d- and the f-terms.

‡ For  $m = 7$ ,  $md_1 = 10\,099$ ,  $n^* = 6.593$ ;  $md_1 = 10\,054$ ,  $n^* = 6.607$ .Be Z = 4.  $N_{Be} = 109\,730.5$ .

Be I (31); cf. (234, 236). Only the triplet system is known.

Symbol	( $2^3S_1$ )	( $2^3P_0$ )	( $2^3P_1$ )	( $2^3P_2$ )	( $3^3S_1$ )	( $3^3D$ )
Term	23 110.2	53 212.9	53 212.2	53 209.8	10 685.0	13 137.5
n; n*	3; 2.179	2; 1.436	2; 1.436	2; 1.436	3.204	2; 2.890
m	4	5	6	7	8	
ms ( $m^3S_1$ )	6 186.9	4 033.0				
n*	4.212	5.216				
md ( $m^3D$ )	7 249.2	4 589.7	3 165.7	2 315.5	1 760.1	
n*	3.890	4.889	5.888	6.886	7.896	

Be II (31); cf. (212). Spectrum is analogous to that of Li I.

m	1	2	3	4	5
$ms (m^2S_1)$	146 880.5	58 649.3	31 424.8	19 546.3	
n; n*	2; 1.729	2.736	3.738	4.739	
$mp_1 (m^2P_1)$		114 951.7			
n; n*		2; 1.954			
$mp_1 (m^2P_2)$		114 945.1	50 384.7	28 120.2	17 910.2
n; n*		2; 1.954	2.951	3.951	4.950
$md (m^2D)$			48 827.4	27 460.4	17 574.6
n; n*			2; 2.998	3.998	4.997
$mf (m^2F)$				27 435.0	17 558.0
n; n*				4; 4.000	5.000

Bi Z = 83.  $N_{Bi} = 109\,736.8$ .

Bi I (108, 311, 312); cf. (248). System is tentative; inner quantum numbers not assigned.

m	1	2	3	4	5	6
$ms$		26 157	11 373	6 491	4 194	2 930
n; n*		7; 2.048	3.106	4.112	5.116	6.119
$2p_1$	$2p_1$	$2p_1$	$2p_1$	$2p_1$	$2p_1$	$2p_1$
n*	n*	n*	n*	n*	n*	n*
58 745	47 327	43 308	37 086	37 084	25 580	17 618
1.355	1.523	1.611	1.720	1.720	2.071	2.496



Bi I.—(Continued)

m	1	2	3	4	5	6
md <sub>4</sub>			14 833	7 727	4 868	
n*			2.720	3.769	4.748	
md <sub>3</sub>			13 928			
n*			2.807			
md <sub>2</sub>			13 880	7 588	4 770	
n*			2.812	3.803	4.797	
md <sub>1</sub>			12 830			
n*			2.924			

C Z = 6. N<sub>C</sub> = 109 731.7.  
C I (22, 249).  
C II (78); cf. (22, 87). Limits are not accurately known, and are calculated for 4N<sub>H</sub> instead of 4N<sub>C</sub>.

m	2	3	4	5	6	7
x† (?)	100 165					
n*	2.093					
ms (m <sup>2</sup> S <sub>1</sub> )	80 121	39 425	23 311	(15 387)	(10 912)	
n; n*	3; 2.340	3.336	4.338	5.340	6.341	
mp <sub>2</sub> (m <sup>2</sup> P <sub>1</sub> )	196 670	64 934	34 140			
n; n*	2; 1.494	2.599	3.585			
mp <sub>1</sub> (m <sup>2</sup> P <sub>2</sub> )	196 612	64 923	34 134			
n; n*	2; 1.494	2.600	3.585			
md <sub>2</sub> (m <sup>2</sup> D <sub>2</sub> )		51 108.9	28 535.1			
n; n*		3; 2.930	3.921			
md <sub>1</sub> (m <sup>2</sup> D <sub>3</sub> )		51 107.6	28 534.7	18 164	(12 558)	(9 193)
n; n*		3; 2.930	3.921	4.915	5.911	6.908
mf (m <sup>2</sup> F)			27 680	17 703	12 283	(9 017)
n; n*			4; 3.981	4.978	5.976	6.974

† This term combines with p<sub>1</sub> and p<sub>2</sub>.  
C III (28).

Singlet system

1S(1<sup>1</sup>S<sub>0</sub>)|375 463.1|n = 2; n\* = 1.622|2P(2<sup>1</sup>P<sub>1</sub>)|273 111.0|n = 2; n\* = 1.902

Triplet system

m	2	3	m	2	3	4
ms (m <sup>2</sup> S <sub>1</sub> )	146 197.2		mp <sub>1</sub> (m <sup>2</sup> P <sub>2</sub> )	331 939.2	124 685.8	
n; n*	3; 2.598		n; n*	2; 1.726	2.816	
mp <sub>2</sub> (m <sup>2</sup> P <sub>0</sub> )		124 704.1	md (m <sup>2</sup> D)		114 387.2	
n; n*		2; 2.816	n; n*		3; 2.939	
mp <sub>1</sub> (m <sup>2</sup> P <sub>1</sub> )		124 698.6	mf (m <sup>2</sup> F)			62 600.0
n; n*		2; 2.816	n; n*			4; 3.972

C IV (212). δ = ±100. Spectrum analogous to that of Li I.

m	1	2	m	2	3
ms (m <sup>2</sup> S <sub>1</sub> )	520 034	217 302	mp <sub>1</sub> (m <sup>2</sup> P <sub>2</sub> )	455 445	
n; n*	2; 1.838	2.843	n; n*	2; 1.963	
mp <sub>2</sub> (m <sup>2</sup> P <sub>1</sub> )		455 553	md (m <sup>2</sup> D)		195 333
n; n*		2; 1.963	n; n*		3; 2.998

Ca Z = 20. N<sub>Ca</sub> = 109 735.6.  
Ca I (128, 154, 222, 257, 265, 267). Terms (76) based on (270).  
Anomalous terms (41, 104, 237, 257).

Singlet system

m	1	2	3	4	5	6
ms (m <sup>1</sup> S <sub>0</sub> )	49 304.8	15 988.2	7 518.4	5 028.0	3 417.3	2 469.4
n; n*	4; 1.492	2.620	3.820	4.672	5.667	6.668
mp (m <sup>1</sup> P <sub>1</sub> )		25 652.4	12 573.1	7 625.9	5 371.4	3 879.6
n; n*		4; 2.068	2.954	3.794	4.520	5.318
md (m <sup>1</sup> D <sub>2</sub> )			27 455.3	12 006.3	6 385.5	4 314.7
n; n*			3; 2.000	3.023	4.145	5.044
mf (m <sup>1</sup> F <sub>3</sub> )				6 961.3	4 500.0	3 122.6
n; n*				4; 3.910	4.938	5.928

m	7	8	9	10	11	12
ms (m <sup>1</sup> S <sub>0</sub> )	1 867.7	1 461.5	1 176.0			
n*	7.665	8.665	9.660			
mp (m <sup>1</sup> P <sub>1</sub> )	2 824.6	2 120.3	1 638.2	1 305.9	1 071.6	888.5
n*	6.234	7.194	8.185	9.167	10.120	
md (m <sup>1</sup> D <sub>2</sub> )	2 994.7					
n*	6.053					
mf (m <sup>1</sup> F <sub>3</sub> )	2 289.7	1 749.8	1 379.8	1 116.3	919.3	
n*	6.923	7.919	8.918	9.910		

Ca I.—(Continued)  
Triplet system, normal terms

m	2	3	4	5	6
ms (m <sup>2</sup> S <sub>1</sub> )	17 765.1	8 830.3	5 323.8	3 565.6	2 556.2
n; n*	5; 2.485	3.525	4.540	5.548	6.552
mp <sub>2</sub> (m <sup>2</sup> P <sub>0</sub> )	34 146.9	12 752.5	6 789.6		
n; n*	4; 1.793	2.934	4.020		
mp <sub>1</sub> (m <sup>2</sup> P <sub>1</sub> )	34 094.6	12 750.3	6 785.6		
n; n*	4; 1.794	2.934	4.022		
mp <sub>1</sub> (m <sup>2</sup> P <sub>2</sub> )	33 988.7	12 730.3	6 777.8	4 342.7	
n; n*	4; 1.797	2.936	4.023	5.027	
md <sub>3</sub> (m <sup>2</sup> D <sub>1</sub> )		28 969.1	11 556.4	6 561.4	4 255.5
n; n*		3; 1.946	3.082	4.090	5.078
md <sub>2</sub> (m <sup>2</sup> D <sub>2</sub> )		28 955.2	11 552.6	6 559.7	4 254.0
n; n*		3; 1.947	3.083	4.090	5.079
md <sub>1</sub> (m <sup>2</sup> D <sub>3</sub> )		28 933.5	11 547.0	6 556.9	4 252.2
n; n*		3; 1.947	3.083	4.091	5.080
mf (m <sup>2</sup> F)			7 133.9†	4 541.5	3 139.5
n; n*			4; 3.922	4.915	5.912

m	7	8	9	10	11	12
ms (m <sup>2</sup> S <sub>1</sub> )	1 922.4	1 498.6	1 201.1	984.1	819.8	
n*	7.556	8.557	9.559			
md <sub>3</sub> (m <sup>2</sup> D <sub>1</sub> )	3 002.4	2 268.2	1 848.9	1 551.2	1 272.7	
n*	6.046	6.958	7.704	8.411	9.286	
md <sub>2</sub> (m <sup>2</sup> D <sub>2</sub> )	3 000.6	2 264.5	1 838.7	1 547.0	1 270.7	
n*	6.047	6.961	7.726	8.428	9.293	
md <sub>1</sub> (m <sup>2</sup> D <sub>3</sub> )	2 998.2	2 259.3	1 828.8	1 539.1	1 268.2	1 045.4
n*	6.053	6.969	7.747	8.444	9.302	10.246
mf (m <sup>2</sup> F)	2 298.1	1 754.1	1 382.3	1 117.7	921.3	772.8
n*	6.911	7.910	8.910	9.908		

m	13	14	15	16	17
md <sub>1</sub> (m <sup>2</sup> D <sub>3</sub> )	869.6	733.8	627.9	541.0	473.5
mf (m <sup>2</sup> F)	660				

Triplet system, anomalous terms

m	2	3	4	5	6
mp <sub>1</sub> (m <sup>2</sup> P <sub>0</sub> )	10 887.1	780.6	-4 977.5	-8 306.4	
mp <sub>2</sub> (m <sup>2</sup> P <sub>1</sub> )	10 839.9	767.1	-4 983.6	-8 313.1	-10 063
mp <sub>1</sub> (m <sup>2</sup> P <sub>2</sub> )	10 753.0	741.1	-4 999.8	-8 333.6	-10 086

† 4f-term is a triplet.

Ca II (74, 75, 165, 244). Term values calculated from data (76) and 4f-limit (90); corrected to int. scale. Spectrum analogous to that of K I.

m	1	2	3	4	5	6
ms (m <sup>2</sup> S <sub>1</sub> )	95 723.7	43 556.7	25 046.1	16 294	11 447	
n; n*	4; 2.141	3.175	4.186	5.190	6.192	
mp <sub>2</sub> (m <sup>2</sup> P <sub>1</sub> )		70 532.1				
n; n*		4; 2.495				
mp <sub>1</sub> (m <sup>2</sup> P <sub>2</sub> )		70 309.3				
n; n*		4; 2.499				
md <sub>2</sub> (m <sup>2</sup> D <sub>2</sub> )			82 073.5	38 884.5	23 001.6	
n; n*			3; 2.313	3.360	4.368	
md <sub>1</sub> (m <sup>2</sup> D <sub>3</sub> )			82 012.7	38 865.3	22 992.9	15 216†
n; n*			3; 2.314	3.360	4.369	5.371
mf (m <sup>2</sup> F)				27 670	17 707	12 295†
n; n*				4; 3.983	4.980	5.975

† For m = 7, md<sub>1</sub> = 10 799, n\* = 6.375 and mf = 9 044, n\* = 6.967.

Cb Z = 41. N<sub>Cb</sub> = 109 736.5 (187).  
Cd Z = 48. N<sub>Cd</sub> = 109 736.6.

Cd I (70, 90, 128, 131, 222, 223, 225, 227, 259, 264, 326). Terms (76, 274). Not much difference between value of 2P-limits used here and those of Fues (90) when corrected to int. scale.

Singlet system

m	1	2	3	4	5	6
ms (m <sup>1</sup> S <sub>0</sub> )	72 538.8	19 229.3	9 452.1	5 634.1	3 739.2	2 665.7
n; n*	5; 1.230	2.388	3.407	4.413	5.418	6.416
mp (m <sup>1</sup> P <sub>1</sub> )		28 846.6	12 633	7 038	4 480	3 100
n; n*		5; 1.949	2.947	3.948	4.949	5.950
md (m <sup>1</sup> D <sub>2</sub> )			13 319.2	7 404.9	4 701.7	3 246.3
n; n*			5; 2.870	3.850	4.831	5.841

m	7	m	7	8	9
ms (m <sup>1</sup> S <sub>0</sub> )	1 995.6	mp (m <sup>1</sup> P <sub>1</sub> )	2 273	1 739	1 371
n*	7.418	n*	6.949	7.943	8.947



## Cd I.—(Continued)

## Triplet system

m	2	3	4	5	6	7
$m_s (m^3S_1)$	21 054.7	9 975.6	5 857.3	3 856.6	2 732.9	2 037.6
$n; n^*$	6; 2.286	3.317	4.328	5.335	6.337	7.338
$mp_3 (m^3P_0)$	42 424.5	14 147.9	7 542.9	4 709.2	3 224.3	
$n; n^*$	5; 1.608	2.785	3.814	4.827	5.834	
$mp_2 (m^3P_1)$	41 882.6	14 077.2	7 517.5	4 696.7	3 217.4	
$n; n^*$	5; 1.618	2.792	3.821	4.834	5.840	
$mp_1 (m^3P_2)$	40 711.5	13 903.1	7 446.0	4 663.6	3 198.6	2 331.5
$n; n^*$	5; 1.642	2.810	3.839	4.850	5.857	6.861
$md_3 (m^3D_1)$		13 052.4	7 185.3	4 549.9	3 139.2	
$n; n^*$		5; 2.899	3.908	4.911	5.913	
$md_2 (m^3D_2)$		13 040.7	7 179.5	4 546.3	3 138.5	
$n; n^*$		5; 2.901	3.909	4.913	5.913	
$md_1 (m^3D_3)$		13 022.5	7 171.3	4 541.3	3 134.3	2 294.5
$n; n^*$		5; 2.903	3.912	4.915	5.917	6.916
$mf (m^3F)$			6 957.1	(4 445.1)		
$n; n^*$			4; 3.971	4.969		

m	8	9	10	11	12	13
$m_s (m^3S_1)$	1 576.8	1 257.0				
$n^*$	8.342	9.344				
$md_1 (m^3D_1)$	1 751.3	1 379.3	1 114.3	920.3	771.6	658.1†
$n^*$	7.916	8.919	9.924			

†  $14d_1 = 566.7$ .

## Cd II (261). Spectrum analogous to that of Ag I.

m	1	2	3	4	5	6
$m_s (m^3S_1)$	136 376.6	53 386.4		18 335.5	12 624.3	9 223.2
$n; n^*$	5; 1.791	2.868		4.893	5.896	6.899
$mp_3 (m^3P_1)$		92 241.3	41 665.8	24 001.7	15 722.4	
$n; n^*$		5; 2.181	3.245	4.276	5.285	
$mp_2 (m^3P_2)$		89 758.1	40 992.5	23 886.3	15 668.0	
$n; n^*$		5; 2.210	3.272	4.287	5.293	
$md_3 (m^3D_2)$			46 685.3	26 202.1	16 854.0	11 762.4
$n; n^*$			5; 3.066	4.093	5.104	6.108
$md_2 (m^3D_3)$			46 531.0	26 128.6	16 814.2	11 738.9
$n; n^*$			5; 3.071	4.099	5.109	6.114
$mf_3 (m^3F_3)†$				27 955.1		12 386.8
$n; n^*$				4; 3.962		5.963
$mf_2 (m^3F_2)†$				27 942.3	17 828.7	12 403.0
$n; n^*$				4; 3.963	4.968	5.949
$mg (m^3G)$						12 223.2
$n; n^*$						6; 5.993

m	7	8	9
$m_s (m^3S_1)$	7 033.8	5 540.6	
$n^*$	7.900	8.901	
$md_3 (m^3D_2)$	8 678.8	6 667.6	
$n^*$	7.112	8.114	
$md_2 (m^3D_3)$	8 663.9	6 657.7	5 275.8
$n^*$	7.118	8.120	9.121
$mf_3 (m^3F_3)$	9 092.5		
$n^*$	8.948		
$mf_2 (m^3F_2)$	9 126.5		
$n^*$	8.936		
$mg (m^3G)$	8 977.9	6 872.1	
$n^*$	8.992	7.992	

† Some f-pairs are inverse.

Cl Z = 17.  $N_{Cl} = 109 735.4$ .

Cl II (24, 122, 124); Cl III (24, 232); Cl IV (24); Cl V (24, 213); Cl VI (27).

Cl VII (26).

Co Z = 27.  $N_{Co} = 109 736.1$ .

Co I (56, 57, 200, 216).

Cr Z = 24.  $N_{Cr} = 109 736.0$ .

Cr I (47, 50, 51, 52, 96, 98, 138, 141, 146). Terms (97) have been corrected to int. scale; an additional quintet p-term is given (7 664.7, 7 575.7, 7 521.1) which is not included here. Here (') and (") do not indicate that the term is anomalous. 2P terms are inverse.

## Cr I.—(Continued)

## Quintet system

m	2	3	4	5	6
$m_s (m^5S_2)$	46 950.0	16 660.0	8 575.1	5 221.4	
$n; n^*$	4; 1.529	2.568	3.577	4.585	
$mp_3 (m^5P_1)$	27 741.5	15 632.3	10 066.6	7 477.0	
$mp_2 (m^5P_2)$	27 747.2				
$mp_1 (m^5P_3)$	27 755.9				
$mp'_1 (m^5P'_1)$	25 122.1	13 612.8	9 188.5		
$mp'_2 (m^5P'_2)$	24 958.4	13 560.1	9 180.7		
$mp'_3 (m^5P'_3)$	24 718.5	13 499.5	9 165.1		
$mp''_1 (m^5P''_1)$	20 408.1	10 417.0			
$mp''_2 (m^5P''_2)$	20 352.5	10 356.3			
$mp''_3 (m^5P''_3)$	20 291.5	10 283.4			
$md_5 (m^5D_0)$		46 792.4			
$md_4 (m^5D_1)$		46 732.4	8 972.6		
$md_3 (m^5D_2)$		46 615.9	8 954.3		
$md_2 (m^5D_3)$		46 148.2	8 922.7		
$md_1 (m^5D_4)$		46 235.5	8 877.5		
$mf_5 (m^5F_1)$			23 755.8	13 636.7	9 440.5
$mf_4 (m^5F_2)$			23 684.4	13 571.7	9 372.8
$mf_3 (m^5F_3)$			23 577.8	13 457.0	9 287.6
$mf_2 (m^5F_4)$			23 436.7	13 318.2	9 156.4
$mf_1 (m^5F_5)$			23 262.7	13 149.4	8 998.4

## Septet system

m	1	2	3	m	3	4
$m_s (m^7S_3)$	54 542.8	17 647.5	8 899.5	$md_5 (m^7D_1)$	12 289.5	6 843.7
$n; n^*$	4; 1.419	2.494	3.511	$n; n^*$	4; 2.988	4.004
$mp_3 (m^7P_2)$		31 238.4		$md_4 (m^7D_2)$	12 288.3	6 842.4
$n; n^*$		4; 1.874		$n; n^*$	4; 2.988	4.004
$mp_2 (m^7P_3)$		31 157.0		$md_3 (m^7D_3)$	12 286.7	6 840.5
$n; n^*$		4; 1.877		$n; n^*$	4; 2.989	4.005
$mp_1 (m^7P_4)$		31 044.5		$md_2 (m^7D_4)$	12 281.5	6 837.7
$n; n^*$		4; 1.880		$n; n^*$	4; 2.989	4.006
$mp'_3 (m^7P'_2)$		26 814.5		$md_1 (m^7D_5)$	12 281.7	6 833.2
$n; n^*$		4; 2.023		$n; n^*$	4; 2.989	4.007
$mp'_2 (m^7P'_3)$		26 723.9				
$n; n^*$		4; 2.026				
$mp'_1 (m^7P'_4)$		26 608.1				
$n; n^*$		4; 2.031				

Cr II (138, 194); Cr III (95); Cr IV (94); Cr V (93).

Cs Z = 55.  $N_{Cs} = 109 736.7$ .

Cs I (15, 127, 163, 221, 224, 238, 239, 258, 263) s-, p-, d-terms (76), f-, g-, h-terms (202, 203).

m	1	2	3	4	5	6
$m_s (m^2S_1)$	31 404.6	12 868.9	7 087.8	4 494.9	3 105.5	2 274.0
$n; n^*$	6; 1.869	2.920	3.934	4.941	5.944	6.947
$mp_2 (m^3P_1)$		20 226.3	9 639.2	5 695.3	3 768.4	2 678.2
$n; n^*$		6; 2.592	3.574	4.590	5.596	6.401
$mp_1 (m^3P_2)$		19 672.3	9 458.1	5 614.7	3 723.3	2 651.4
$n; n^*$		6; 2.562	3.408	4.421	5.429	6.433
$md_3 (m^3D_2)$			16 905.0	8 815.6	5 356.5	3 592.7
$n; n^*$			5; 2.548	3.528	4.526	5.527
$md_2 (m^3D_3)$			16 807.1	8 772.8	5 335.6	3 581.1
$n; n^*$			5; 2.555	3.537	4.535	5.535
$mf_3 (m^3F_3)†$				6 934.2	4 435.1	3 076.9
$n; n^*$				4; 3.977	4.975	5.972
$mf_2 (m^3F_2)†$				6 934.4	4 435.3	3 077.0
$n; n^*$				4; 3.977	4.975	5.972
$mg (m^3G)†$					4 395.6	3 059
$n; n^*$					5; 4.997	5.990
$mh (m^3H)†$						3 049.2
$n; n^*$						6; 5.999

m	7	8	9	10	11	12
$m_s (m^2S_1)$	1 738					
$n^*$	7.946					
$mp_2 (m^3P_1)$	2 002.2	1 551.0	1 238.6	1 010.1		
$n^*$	7.403	8.411	9.412	10.423		
$mp_1 (m^3P_2)$	1 985.1	1 539.6	1 230.6	1 004.8	836.5	707.1
$n^*$	7.435	8.442	9.443	10.451		
$md_2 (m^3D_2)$	2 575.7	1 936.1	1 508.3	1 208.6	996.4	828.5
$n^*$	8.527	7.529	8.530	9.529		
$md_1 (m^3D_3)$	2 567.5	1 931.7	1 505.0	1 207.5	988.7	823.1
$n^*$	6.537	7.537	8.539	9.533		



Cs I.—(Continued)

$m$	7	8	9	10	11	12	
$mf_2 (m^2F_3) \dagger$	2 258.5	1 727.7	1 364.1	1 104.3	912.1	765.8	
$n^*$	6.970	7.969	8.969	9.969			
$mf_1 (m^2F_4) \dagger$	2 258.5	1 727.8	1 364.2	1 104.3	912.1		
$n^*$	6.970	7.969	8.969	9.969			
$m$	13	14	15	16	17	18	
$mp_1 (m^2P_2)$	605.4	525.1	459.3	405.8	359.9	322.3	
$m$	19	20	21	22	23	24	25
$mp_1 (m^2P_2)$	289.1	261.6	238.3	217.5	199.6	183.3	169.4
$m$	26	27	28	29	30	31	32
$mp_1 (m^2P_2)$	157.1	145.4	135.9	125.4	117.7	109.6	103.2

† Not quite consistent with terms  $s$ ,  $p$ ,  $d$ ;  $f$ -terms are inverse.

Cs II (5).

Cu  $Z = 29$ .  $N_{Cu} = 109 736.2$ .

Cu I (8, 129, 133, 239, 283, 284, 285, 291, 293, 301).

Limits (76). Higher terms (307) from observations (116, 323).

m	1	2	3	4	5	6
$ms (m^2S_1)$	62 308.0	19 171.1	9 459.5	5 636.7	3 739.2	2 659.2
$n; n^*$	4; 1.327	2.392	3.406	4.412	5.417	6.424
$mp_2 (m^2P_1)$		31 772.8	12 957.7†			
$n; n^*$		4; 1.859	2.909			
$mp_1 (m^2P_1)$		31 524.4	12 925.0†			
$n; n^*$		4; 1.865	2.913			
$md_2 (m^2D_2)$		49 062.6‡	12 372.8	6 920.8	4 415.2	3 061
$n; n^*$		(3) 1.496	4; 2.978	3.982	4.986	5.988
$md_1 (m^2D_1)$		51 105.2‡	12 365.9	6 917.1	4 413.4	3 059.7‡
$n; n^*$		(3) 1.466	4; 2.979	3.983	4.987	5.989
$mf (m^2F)$				6 879.2	4 401.8	
$n; n^*$				4; 3.994	4.993	

† From combinations with  $2d$  found by Werner (320), see (21).‡  $2d_1$  and  $2d_2$  are inverse.§ For  $m = 7$ ,  $md_1 = 2 257.2$ ,  $n^* = 6.974$ ; for  $m = 8$ ,  $md_1 = 1 721.8$ ,  $n^* = 7.982$ .

Cu II (286).

F  $Z = 9$ .  $N_F = 109 734.0$ .

F I (22, 35, 37, 42, 67, 68, 69).

F II, F III and F IV (22).

Fe  $Z = 26$ .  $N_{Fe} = 109 736.0$ .

Fe I (50, 54, 55, 98, 99, 113, 114, 157, 160, 188, 254, 297, 304, 315, 317).

Fe II (194).

Ga  $Z = 31$ .  $N_{Ga} = 109 736.3$ .

Ga I (235). Limits (314).

m	2	3	4	5	6	7
$ms (m^2S_1)$	23 593.6	10 797.5	6 224.3	4 050.8	2 852.3	
$n; n^*$	5; 2.156	3.187	4.199	5.204	6.202	
$mp_2 (m^2P_1)$	48 382.2		8 006.4	4 941.4		
$n; n^*$	4; 1.507		3.703	4.712		
$mp_1 (m^2P_1)$	47 555.9		7 965.3	4 920.5		
$n; n^*$	4; 1.519		3.712	4.722		
$md_2 (m^2D_2)$		13 600.5	7 579.4	4 807.9		
$n; n^*$		4; 2.841	3.806	4.778		
$md_1 (m^2D_1)$		13 594.2	7 570.9	4 803.4	3 306.8	2 357.1
$n; n^*$		4; 2.842	3.807	4.780	5.761	6.823

†  $n$  changed from value of (21) to accord with observations of (150).

Ga III (240).

Ge  $Z = 32$ .

Ge I (91, 176, 242); Ge IV (43, 288).

Gl  $Z = 4$ ; see Be.H  $Z = 1$ .  $N_H = 109 677.7$ ,  $\frac{1}{\lambda} = N_H \left( \frac{1}{m_1^2} + \frac{1}{m_2^2} \right)$ ,  $m_1 < m_2$ .

m	1	2	3	4	5	6
$N_H/m^2$	109 677.7	27 419.4	12 186.41	6 854.85	4 387.11	3 046.60
m	7	8	9	10	11	12
$N_H/m^2$	2 238.32	1 713.71	1 354.05	1 096.78	906.43	761.65
m	13	14	15	16	17	18
$N_H/m^2$	648.98	559.58	487.46	428.43	379.51	338.51

H.—(Continued)

m	19	20	21	22	23	24
$N_H/m^2$	303.82	274.19	248.70	226.61	207.33	190.41
m	25	26	27	28	29	30
$N_H/m^2$	175.48	162.25	150.45	139.90	130.41	121.86†

Series observed:  $m_1 = 1$  (167), 2 (6, 327), 3 (221), 4 (32); discussion of data (162); theory of fine structure (18, 19, 294).†  $N_H/(31)^2 = 114.13$ .He  $Z = 2$ .  $N_{He} = 109 722.2$ .

He I has 2 systems of terms; He II has one.

He I (126, 170, 221, 222, 250, 268). Terms (234)

Singlet system ("Parhelium")

m	1	2	3	4	5	6
$mS (m^1S)$	198 284.1†	32 033.3	13 445.9	7 370.5	4 647.2	3 195.8
$n; n^*$	1; 0.744	1.851	2.857	3.859	4.859	5.860
$mP (m^1P)$		27 175.9	12 101.4	6 818.1	4 368.3	3 035.8
$n; n^*$		2; 2.010	3.011	4.012	5.013	6.018
$mD (m^1D)$			12 205.8	6 864.3	4 392.5	3 050.0
$n; n^*$			3; 2.998	3.998	4.998	5.998
$mF (m^1F)$				6 857.8	4 390.7	
$n; n^*$				4; 4.000	5.000	
$mG (m^1G)$					4 391	
$n; n^*$					5; 4.999	

m	7	8	9	10	11	12
$mS (m^1S)$	2 331.8	1 776.0	1 397.9	1 128.6		780.7†
$n^*$	6.860	7.861	8.861	9.860		
$mP (m^1P)$	2 231.6	1 709.4	1 351.1	1 094.6	904.8	760.4
$n^*$	7.013	8.012	9.012	10.013		
$mD (m^1D)$	2 240.7	1 715.3	1 355.5	1 097.9	907.4	762.5
$n^*$	6.998	7.998	8.999	9.998		

m	13	14	15	16	17	18
$mP (m^1P)$	648.1	558.9	486.9	428.0	379.1	338.2‡
$mD (m^1D)$	649.8	560.1				

Doublet system ("Orthohelium")

m	2	3	4	5	6	7
$ms (m^2S_1)$	38 454.7	15 073.9	8 012.5	4 963.7	3 374.5	2 442.4
$n; n^*$	2; 1.689	2.698	3.701	4.702	5.703	6.703
$mp_2 (m^2P_1)$	29 222.9					
$n; n^*$	2; 1.938					
$mp_1 (m^2P_1)$	29 223.9	12 746.1	7 093.6	4 509.9	3 117.8	2 283.3
$n; n^*$	2; 1.938	2.934	3.933	4.932	5.933	6.933
$md (m^2D)$		12 209.1	6 866.2	4 393.5	3 050.6	2 241.0
$n; n^*$		3; 2.998	3.998	4.998	5.998	6.998
$mf (m^2F)$			6 858.2	4 389.0		
$n; n^*$			4; 4.000	5.000		
$mg (m^2G)$				4 391		
$n; n^*$				5; 4.999		

m	8	9	10	11	12	13	14
$ms (m^2S_1)$	1 849.2	1 448.6	1 165.2	958.0	801.3	680.0	583.9
$n^*$	7.704	8.705	9.705				
$mp_1 (m^2P_1)$	1 743.9	1 375.3	1 112.4	918.0	770.6	655.9	565.1
$n^*$	7.932	8.933	9.932				
$md (m^2D)$	1 715.6	1 355.4	1 097.7	907.2	762.3	649.5	560.1
$n^*$	7.998	8.998	9.998				

m	15	16	17	18	19	20	21
$ms (m^2S_1)$	508.4						
$mp_1 (m^2P_1)$	491.9	432.1	382.5	341.0	305.9	275.9	250.2‡
$md (m^2D)$	488.0	428.6	379.7	338.3	303.6	273.6	248.5

2p-terms are inverse; 5G and 5g from (233); theoretically doublets should be unresolved triplets, hence Russell-Saunders' notation is doubtful, cf.  $j$ -values (220, 247); several series which violate the  $k$  selection rule have been observed in electric fields (71, 147, 164, 290, 313); Lyman (170) records a line which he thinks represents a combination between a doublet and a singlet term.

† (22, 169).

‡  $13S = 655.2$ .§  $19P = 303.6$ ,  $20P = 274.0$ ||  $22p_1 = 227.9$ .



## He II.

$$\frac{1}{\lambda} = 4N_{\text{He}} \left( \frac{1}{m_1^2} - \frac{1}{m_2^2} \right), m_1 < m_2$$

m	1	2	3	4	5	6
$4N_{He}/m^2$	438 888.8	109 722.2	48 765.4	27 430.55	17 555.55	12 191.36
m	7	8	9	10	11	12
$4N_{He}/m^2$	8 156.91	6 857.64	5 418.38	4 388.89	3 627.18	3 047.84
m	13	14	15	16	17	18
$4N_{He}/m^2$	2 596.98	2 239.23	1 950.62	1 714.41	1 518.65	1 354.59
m	19		20		21	
$4N_{He}/m^2$	1 215.76		1 097.22		995.21	

Series observed:  $m_1 = 1$  (170), 2 (165), 3 (73), 4 (228); for  $m_1 = 4$ , lines corresponding to even values of  $m_2$  are observed in stellar spectra and there called Pickering lines of H. Theory of fine structure (18, 19, 294).

Hg Z = 80.  $N_{\text{Hg}} = 109 736.8$ .

Hg I (90, 128, 131, 166, 221, 222, 223, 225, 226, 227, 252, 259, 264, 277, 324, 326). Terms:  $g, h, i$  (115) very inaccurate, others (234) nearly identical with Fowler's (76). Differentiation of  $F$ - and  $f$ -terms not certain. Dingle (66) gives different arrangement.

## Singlet system

m	1	2	3	4	5	6
$mS$ ( $m^1S_0$ )	84 181.2	20 253.0	9 776.6	5 777.1	3 815.7	
$n; n^*$	6; 1.142	2.328	3.350	4.368	5.363	
$mP$ ( $m^1P_1$ )		30 112.5	12 886.1	7 319.0†	5 368.2	4 217.2
$n; n^*$		6; 1.909	2.919	3.872	4.522	5.102
$mD$ ( $m^1D_2$ )			12 848.0	7 117.2	4 520.7	3 123.9
$n; n^*$			6; 2.922	3.926	4.927	5.927
$mF$ ( $m^1F_3$ )				6 939.8	4 438.3	
$n; n^*$				5; 3.976	4.973	
m	7	8	9	10	11	12
$mP$ ( $m^1P_1$ )	3 026.9	2 237.6	1 717.2	1 355.1	1 097.3	900.8†
$n^*$	6.021	7.003	7.994	9.000	10.000	
$mD$ ( $m^1D_2$ )	2 288.1	1 745.8	1 376.1	1 111.5		
$n^*$	6.926	7.929	8.930	9.936		

## Triplet system

m	2	3	4	5	6	7
$mS$ ( $m^3S_1$ )	21 830.8	10 219.9	5 964.8	3 912.8	2 765.0	2 057.5
$n; n^*$	7; 2.242	3.277	4.289	5.296	6.299	7.303
$mp_1$ ( $m^3P_0$ )	46 536.2	14 664.5	7 734.4	4 805.8	3 279.6	2 381.3
$n; n^*$	6; 1.535	2.735	3.767	4.779	5.784	6.788
$mp_2$ ( $m^3P_1$ )	44 768.9	14 519.1	7 714.6	4 768.7	3 264.7	2 373.7
$n; n^*$	6; 1.565	2.749	3.771	4.798	5.798	6.800
$mp_1$ ( $m^3P_2$ )	40 138.3	12 973.5	7 357.8	4 570.5	3 158.4	2 307.4
$n; n^*$	6; 1.663	2.908	3.862	4.900	5.893	6.896
$md_1$ ( $m^3D_1$ )		12 845.0	7 096.5	4 502.7	3 110.2	2 279.4
$n; n^*$		6; 2.922	3.932	4.938	5.940	6.939
$md_2$ ( $m^3D_2$ )		12 785.0	7 073.2	4 491.0	3 104.5	2 273.1
$n; n^*$		6; 2.930	3.938	4.943	5.945	6.948
$md_1$ ( $m^3D_3$ )		12 749.9	7 051.7	4 478.7	3 096.3	2 269.6
$n; n^*$		6; 2.934	3.946	4.950	5.953	6.954
$mf_1$ ( $m^3F_2$ )			6 938.4	4 436.3		
$n; n^*$			5; 3.976	4.974		
$mf_2$ ( $m^3F_3$ )			6 936.9	4 432.2	3 074.8	2 254.1
$n; n^*$			5; 3.977	4.977	5.974	6.977
$mf_1$ ( $m^3F_4$ )			6 937	4 432		
$n; n^*$			5; 3.977	4.977		
$mg$ ( $m^3G$ )				4 395	3 053	2 243
$n; n^*$				5; 4.997	5.995	6.995
$mh$ ( $m^3H$ )					(3 038)	(2 237)
$n; n^*$					6; 6.010	7.004
$mi$ ( $m^3I$ )						(2 216)
$n; n^*$						7; 7.037
m	8	9	10	11	12	13
$mS$ ( $m^3S_1$ )	1 590.3	1 265.6	1 030.7	855.1		616.8
$n^*$	8.307	9.312	10.318			
$mp_2$ ( $m^3P_1$ )	1 802.3	1 415.4	1 142.0			
$n^*$	7.803	8.805	9.802			
$mp_1$ ( $m^3P_2$ )	1 759.3	1 387.7	1 120.1	925.2	775.6	662.8
$n^*$	7.898	8.892	9.898			
$md_1$ ( $m^3D_1$ )	1 734.5	1 366.4	1 105.2	911.7	764.2	650.5
$n^*$	7.954	8.952	9.955			

## Hg I. Triplet system.—(Continued)

m	14	15	16	17	18	19
$ms$ ( $m^3S_1$ )	532.0	464.1	409.4			
$mp_1$ ( $m^3P_2$ )	568.3	493.5	436.0	388.5	347.0	
$md_1$ ( $m^3D_3$ )	559.1	486.8	427.2	376.9	335.4	301.0**

† From (319).

‡ 13P = 761.0.

§ From (115).

|| 8d<sub>2</sub> = 1739.4, n\* = 7.942.

¶ 8f<sub>2</sub> = 1723.2, n\* = 7.980.

\*\* 20d<sub>1</sub> = 269.2, 21d<sub>1</sub> = 243.8.

In Z = 49.  $N_{\text{In}} = 109 736.6$ .

In I (130, 235). Limits (314).

m	2	3	4	5	6	7
$ms$ ( $m^3S_1$ )	22 289.2	10 360.4	6 025.2	3 943.4	2 781.2	2 063.0
$n; n^*$	6; 2.212	3.254	4.268	5.276	6.281	7.294
$mp_2$ ( $m^3P_1$ )	46 662.1		7 801.2	4 836.7	3 290.7	2 386
$n; n^*$	5; 1.533		3.751	4.764	5.774	6.782
$mp_1$ ( $m^3P_2$ )	44 449.3		7 689.9	4 780.1	3 261.3	2 364
$n; n^*$	5; 1.571		3.777	4.792	5.801	6.813
$md_2$ ( $m^3D_2$ )		13 770.0	7 613.5	4 824.0	3 322.8	2 437
$n; n^*$		5; 2.823	3.796	4.770	5.747	6.710
$md_1$ ( $m^3D_3$ )		13 746.1	7 564.8	4 800.3	3 304.3	2 439.6
$n; n^*$		5; 2.825	3.808	4.782	5.763	6.707

m	8	9	10	11	12
$ms$ ( $m^3S_1$ )	1 594	1 220			
$n^*$	8.298	9.484			
$mp_1$ ( $m^3P_2$ )	1 798				
$n^*$	7.812				
$md_1$ ( $m^3D_3$ )	1 849	1 450	1 168	960	803
$n^*$	7.704	8.700	9.693		

† n changed from value of (21) to accord with observations of (150).

In III (240).

Ir Z = 77.  $N_{\text{Ir}} = 109 736.8$ .

Ir I (197).

K Z = 19.  $N_{\text{K}} = 109 735.6$ .

K I (14, 15, 127, 163, 221, 224, 238, 258, 263).  $p$ -terms (65); others (76) corrected to limit calculated by (65).

m	1	2	3	4	5	6
$ms$ ( $m^3S_1$ )	35 008.5	13 982.9	7 558.3	4 735.4	3 243.1	2 360.1
$n; n^*$	4; 1.771	2.802	3.800	4.814	5.817	6.819
$mp_2$ ( $m^3P_1$ )		22 023.4	10 307.0	6 011.9	3 938.7	2 780.8
$n; n^*$		4; 2.232	3.263	4.272	5.279	6.281
$mp_1$ ( $m^3P_2$ )		21 965.7	10 288.3	6 003.8	3 934.3	2 778.5
$n; n^*$		4; 2.235	3.266	4.275	5.282	6.284
$md$ ( $m^3D$ )			13 472.9†	7 610.9†	4 824.5	3 312.4
$n; n^*$			3; 2.854	3.797	4.770	5.756
$mf$ ( $m^3F$ )				6 881.1	4 406.8	3 059.1
$n; n^*$				4; 3.994	4.991	5.990
$mg$ ( $m^3G$ )					4 389.0	
$n; n^*$					5; 4.999	
$mh$ ( $m^3H$ )						3 042.7
$n; n^*$						6; 6.005

m	7	8	9	10	11	12
$ms$ ( $m^3S_1$ )	1 794.1	1 410.3	1 138.8	939.2		
$n^*$	7.821	8.821	9.816			
$mp_2$ ( $m^3P_1$ )	2 068.4	1 598.4				
$n^*$	7.284	8.286				
$mp_1$ ( $m^3P_2$ )	2 066.7	1 597.3	1 271.7	1 036.2	860.8	726.3
$n^*$	7.287	8.289	9.290	10.291		
$md$ ( $m^3D$ )	2 410.0	1 830.4	1 436.2	1 158.9	958.5	
$n^*$	6.748	7.743	8.741	9.731		
$mf$ ( $m^3F$ )	2 246.9	1 717.4				
$n^*$	6.989	7.994				

m	13	14	15	16	17	18
$mp_1$ ( $m^3P_2$ )	621.2	537.1	469.2	413.4	366.9	327.9
m	19	20	21	22	23	24
$mp_1$ ( $m^3P_2$ )	294.8	266.4	242.0	220.8	202.3	186.0
m	25	26	27	28	29	30
$mp_1$ ( $m^3P_2$ )	171.4	158.7	147.2	137.0	127.8	119.6

† 3d is double and inverse: 3d<sub>1</sub> - 3d<sub>2</sub> = 2.74 (64).

‡ Term value uncertain, lines 2p - 4d abnormally faint.



## K I.—(Continued)

<i>m</i>	31	32	33	34	35	36
<i>mp</i> ( <i>m</i> <sup>2</sup> <i>P</i> <sub>2</sub> )	112.0	105.1	98.9	93.3	88.2	83.3
<i>m</i>	37	38	39	40	41	42
<i>mp</i> ( <i>m</i> <sup>2</sup> <i>P</i> <sub>2</sub> )	78.9	74.6	70.6	66.8	63.8	59.8

‡ 43*p*<sub>1</sub> = 57.4.

K II (34, 36, 62, 63, 219, 249). K IV (124).

Kr *Z* = 36. *N*<sub>Kr</sub> = 109 736.4.

Kr II (135).

La *Z* = 57. *N*<sub>La</sub> = 109 736.7.

La I (106, 107, 190, 191, 192, 237).

La II (107, 237).

Li *Z* = 3. *N*<sub>Li</sub> = 109 728.5.

Li I (15, 127, 149, 163, 221, 224, 258, 263). Limits (76).

<i>m</i>	1	2	3	4	5	6
<i>ms</i> ( <i>m</i> <sup>2</sup> <i>S</i> )	43 486.3	16 280.5	8 475.2	5 187.8	3 500.4	2 535.6
<i>n</i> ; <i>n</i> *	2; 1.588	2.596	3.598	4.599	5.599	6.578
<i>mp</i> ( <i>m</i> <sup>2</sup> <i>P</i> )		28 582.5†	12 560.4	7 018.2	4 473.6	3 099.2
<i>n</i> ; <i>n</i> *		2; 1.966	2.956	3.954	4.953	5.951
<i>md</i> ( <i>m</i> <sup>2</sup> <i>D</i> )			12 203.1	6 863.5	4 389.6	3 047.0
<i>n</i> ; <i>n</i> *			3; 2.999	3.998	5.000	6.001
<i>mf</i> ( <i>m</i> <sup>2</sup> <i>F</i> )				6 856.1	4 381.8	
<i>n</i> ; <i>n</i> *				4; 4.000	5.005	
<i>mg</i> ( <i>m</i> <sup>2</sup> <i>G</i> )					4 386	
<i>n</i> ; <i>n</i> *					5; 5.002	
<i>mh</i> ( <i>m</i> <sup>2</sup> <i>H</i> )						3 042
<i>n</i> ; <i>n</i> *						6; 6.006

<i>m</i>	7	8	9	10	11	12
<i>mp</i> ( <i>m</i> <sup>2</sup> <i>P</i> )	2 273.3	1 736.3	1 372.7	1 113.6	917.2	771.7
<i>n</i> *	6.948	7.749	8.941	9.927		
<i>md</i> ( <i>m</i> <sup>2</sup> <i>D</i> )	2 237.4	1 699.0	1 345.2			
<i>n</i> *	7.003	8.036	9.032			

<i>m</i>	13	14	15	16	17	18
<i>mp</i> ( <i>m</i> <sup>2</sup> <i>P</i> )	658.3	560.7	490.7	429.4	381.2	340.3

<i>m</i>	19	20	21	22	23	24
<i>mp</i> ( <i>m</i> <sup>2</sup> <i>P</i> )	304.9	275.0	248.9	228.3	207.7	188.9

<i>m</i>	25	26	27	28	29	30
<i>mp</i> ( <i>m</i> <sup>2</sup> <i>P</i> )	175.8	160.8	149.9	142.0	131.1	122.5

<i>m</i>	31	32	33	34	35	36
<i>mp</i> ( <i>m</i> <sup>2</sup> <i>P</i> )	114.6	107.8	101.4	95.0	90.9	85.8

<i>m</i>	37	38	39	40	41	42
<i>mp</i> ( <i>m</i> <sup>2</sup> <i>P</i> )	81.6	77.7	73.9	69.4	65.4	62.0

† 2*p* is double, 2*p*<sub>2</sub> - 2*p*<sub>1</sub> = 0.34 (132, 329).

Li II (214, 215, 280, 281, 282, 302, 321, 322). Terms (322.5). Spectrum analogous to that of He I.

## Singlet system ("Parlithium")

<i>m</i>	1	2	3	4	5	6
<i>ms</i> ( <i>m</i> <sup>2</sup> <i>S</i> )	(607 000)	118 718	51 300	28 486	18 083	12 503
<i>n</i> ; <i>n</i> *	1; (0.851)	1.923	2.925	3.925	4.927	5.925
<i>mp</i> ( <i>m</i> <sup>2</sup> <i>P</i> )		108 263	48 330	27 247		
<i>n</i> ; <i>n</i> *		2; 2.013	3.014	4.014		
<i>md</i> ( <i>m</i> <sup>2</sup> <i>D</i> )			48 804	27 454	17 568	12 200
<i>n</i> ; <i>n</i> *			3; 2.999	3.998	4.998	5.998
<i>mf</i> ( <i>m</i> <sup>2</sup> <i>F</i> )				27 435	17 557	12 194
<i>n</i> ; <i>n</i> *				4; 4.000	5.000	6.000

Term	7 <sup>1</sup> <i>S</i>	7 <sup>1</sup> <i>D</i>	7 <sup>1</sup> <i>F</i>	8 <sup>1</sup> <i>D</i>	8 <sup>1</sup> <i>F</i>
<i>n</i> *	9 153	8 962	8 958	6 863	6 857
	6.925	6.998	7.000	7.997	8.001

## Triplet system ("Ortholithium")

<i>m</i>	2	3	4	5	6	7
<i>ms</i> ( <i>m</i> <sup>2</sup> <i>S</i> )	134 041	55 327	30 097	18 895	12 957	9 438
<i>n</i> ; <i>n</i> *	2; 1.810	2.817	3.819	4.820	5.820	6.820
<i>mp</i> ( <i>m</i> <sup>2</sup> <i>P</i> )	115 812	50 578	28 191	17 947	12 422	
<i>n</i> ; <i>n</i> *	2; 1.947	2.946	3.946	4.945	5.944	
<i>md</i> ( <i>m</i> <sup>2</sup> <i>D</i> )		48 834	27 467	17 574	12 203	8 964
<i>n</i> ; <i>n</i> *		3; 2.998	3.998	4.998	5.997	6.997
<i>mf</i> ( <i>m</i> <sup>2</sup> <i>F</i> )			27 435	17 557	12 193	8 958†
<i>n</i> ; <i>n</i> *			4; 4.000	5.000	5.999	7.000

† 8<sup>1</sup>*F* = 6 858, *n*\* = 8.000.Mg *Z* = 12. *N*<sub>M</sub> = 109 734.7.

Mg I (86, 128, 131, 222, 259, 264). Terms (76); anomalous terms, see (111).

## Singlet system

<i>m</i>	1	2	3	4	5	6
<i>ms</i> ( <i>m</i> <sup>2</sup> <i>S</i> )	61 672.1	18 169.0	9 115.8	5 485.7	3 661.6	
<i>n</i> ; <i>n</i> *	3; 1.334	2.457	3.470	4.473	5.474	
<i>mp</i> ( <i>m</i> <sup>2</sup> <i>P</i> <sub>1</sub> )		26 620.7	12 325.5	6 972.6	4 461	3 103
<i>n</i> ; <i>n</i> *		3; 2.030	2.984	3.966	4.960	5.947
<i>md</i> ( <i>m</i> <sup>2</sup> <i>D</i> <sub>2</sub> )			15 268.9	8 537.4	5 363.6	3 648.7
<i>n</i> ; <i>n</i> *			3; 2.681	3.686	4.624	5.484

<i>m</i>	7	8	9	10	11	12
<i>mp</i> ( <i>m</i> <sup>2</sup> <i>P</i> <sub>1</sub> )	2 277	1 741				
<i>n</i> *	6.942	7.939				
<i>md</i> ( <i>m</i> <sup>2</sup> <i>D</i> <sub>2</sub> )	2 631.6	1 982.7	1 544.9	1 237.0	1 012.3	845.4†
<i>n</i> *	6.457	7.440	8.428	9.418	10.412	

## Triplet system

<i>m</i>	2	3	4	5	6	7
<i>ms</i> ( <i>m</i> <sup>2</sup> <i>S</i> <sub>1</sub> )	20 474.5	9 799.3	5 781.3	3 817.0	2 709.1	2 022.1
<i>n</i> ; <i>n</i> *	4; 2.315	3.347	4.357	5.362	6.364	7.366
<i>mp</i> <sub>3</sub> ( <i>m</i> <sup>2</sup> <i>P</i> <sub>0</sub> )	39 821.3					
<i>n</i> ; <i>n</i> *	3; 1.660					
<i>mp</i> <sub>2</sub> ( <i>m</i> <sup>2</sup> <i>P</i> <sub>1</sub> )	39 801.4	13 824.1		4 653.2		
<i>n</i> ; <i>n</i> *	3; 1.660	2.818		4.866		
<i>mp</i> <sub>1</sub> ( <i>m</i> <sup>2</sup> <i>P</i> <sub>2</sub> )	39 760.5	13 820.0	7 419.0	4 651.9	3 184.5	
<i>n</i> ; <i>n</i> *	3; 1.661	2.818	3.846	4.867	5.870	
<i>md</i> ( <i>m</i> <sup>2</sup> <i>D</i> )		13 714.7	7 479.5	4 704.1	3 229.3	2 352.9
<i>n</i> ; <i>n</i> *		3; 2.829	3.830	4.830	5.830	6.829
<i>mf</i> ( <i>m</i> <sup>2</sup> <i>F</i> )			6 994.8	4 469.0		
<i>n</i> ; <i>n</i> *			4; 3.960	4.956		

<i>m</i>	8	9	10	11	12	13
<i>ms</i> ( <i>m</i> <sup>2</sup> <i>S</i> <sub>1</sub> )	1 567.1	1 250.3				
<i>n</i> *	8.368	9.369				
<i>md</i> ( <i>m</i> <sup>2</sup> <i>D</i> )	1 790.3	1 408.5	1 136.4	936.1	784.2	667.6†
<i>n</i> *	7.829	8.827	9.826			

† 13*D* = 716.2. ‡ 14*d* = 574.0.Mg II (74, 75, 165, 245). Term values calculated from data (76) and 4*f*-limit (90), corrected to int. scale. Spectrum analogous to that of Na I.

<i>m</i>	1	2	3	4	5	6
<i>ms</i> ( <i>m</i> <sup>2</sup> <i>S</i> <sub>1</sub> )	121 268.8	51 463.6	28 482.6	18 070.7	12 484.1	9 139.0
<i>n</i> ; <i>n</i> *	3; 1.903	2.920	3.925	4.928	5.930	6.931
<i>mp</i> <sub>2</sub> ( <i>m</i> <sup>2</sup> <i>P</i> <sub>1</sub> )		85 599.4	40 648.0	23 813.9	15 645.7	
<i>n</i> ; <i>n</i> *		3; 2.265	3.286	4.293	5.297	
<i>mp</i> <sub>1</sub> ( <i>m</i> <sup>2</sup> <i>P</i> <sub>2</sub> )		85 507.8	40 617.5	23 799.8	15 638.1	
<i>n</i> ; <i>n</i> *		3; 2.266	3.287	4.294	5.299	
<i>md</i> <sub>2</sub> ( <i>m</i> <sup>2</sup> <i>D</i> <sub>2</sub> )			49 778.4			
<i>n</i> ; <i>n</i> *			3; 2.970			
<i>md</i> <sub>1</sub> ( <i>m</i> <sup>2</sup> <i>D</i> <sub>3</sub> )			49 777.4	27 956.7	17 847.7	12 367.9
<i>n</i> ; <i>n</i> *			3; 2.970	3.982	4.990	5.957
<i>mf</i> ( <i>m</i> <sup>2</sup> <i>F</i> )				27 468.8	17 578.6	12 206.2
<i>n</i> ; <i>n</i> *				4; 3.997	4.997	5.997
<i>mg</i> ( <i>m</i> <sup>2</sup> <i>G</i> )						12 196.0
<i>n</i> ; <i>n</i> *						6; 5.999

<i>m</i>	7	8	9	10	11	12
<i>ms</i> ( <i>m</i> <sup>2</sup> <i>S</i> <sub>1</sub> )	6 976.6	5 502.2				
<i>n</i> *	7.932	8.932				
<i>md</i> <sub>1</sub> ( <i>m</i> <sup>2</sup> <i>D</i> <sub>3</sub> )	9 070.8	6 933.1	5 473.1			
<i>n</i> *	6.956	7.956	8.956			
<i>mf</i> ( <i>m</i> <sup>2</sup> <i>F</i> )	8 967.0	6 865.2	5 423.7	4 393.1	3 630.5	3 050.4
<i>n</i> *	6.996	7.996	8.996	9.996		
<i>mg</i> ( <i>m</i> <sup>2</sup> <i>G</i> )	8 958.9	6 860.6	5 420.7	4 390.8	3 628.7	3 049.1
<i>n</i> *	6.996	7.999	8.999	9.999		

Mn *Z* = 25. *N*<sub>Mn</sub> = 109 736.0.Mn I (49, 50, 105, 175). Terms (45) according to theory (296); *f*-terms (2) have been corrected. All *d*- and *f*-terms of sextet system are inverse. Here ('), ("), . . . do not indicate that the terms are anomalous.

## Sextet system

<i>m</i>	<i>ms</i> ( <i>m</i> <sup>2</sup> <i>S</i> <sub>5</sub> )	<i>mp</i> <sub>3</sub> ( <i>m</i> <sup>2</sup> <i>P</i> <sub>0</sub> )	<i>mp</i> <sub>2</sub> ( <i>m</i> <sup>2</sup> <i>P</i> <sub>1</sub> )	<i>mp</i> <sub>1</sub> ( <i>m</i> <sup>2</sup> <i>P</i> <sub>2</sub> )	<i>mp</i> <sub>2</sub> ' ( <i>m</i> <sup>2</sup> <i>P</i> <sub>1</sub> )	<i>mp</i> <sub>1</sub> ' ( <i>m</i> <sup>2</sup> <i>P</i> <sub>2</sub> )
1	59 937.5†					
2	18 533.5‡	35 158.2	35 149.5	35 135.2	24 247.4	24 211.7
3	9 032.9§					

† *n*\* = 1.353. ‡ *n*\* = 2.432. § *n*\* = 3.486.



## Mn I. Sextet system.—(Continued)

<i>m</i>	$mP_1'$	$mP_2'$	$mP_3'$	$mP_4'$	$mP_5'$	$mP_6'$
2	( $m^6P_4'$ ) 24 167.5	( $m^6P_3'$ ) 14 943.6	( $m^6P_2'$ ) 14 781.4	( $m^6P_1'$ ) 14 678.3	( $m^6P_5'$ ) 10 049.5	( $m^6P_6'$ ) 9 925.1
<i>m</i>	$mD_5$	$mD_4$	$mD_3$	$mD_2$	$mD_1$	$mD_6$
3	( $m^6D_5$ ) 42 300.3	( $m^6D_4$ ) 42 369.0	( $m^6D_3$ ) 42 485.9	( $m^6D_2$ ) 42 665.5	( $m^6D_1$ ) 42 885.1	( $m^6D_6$ ) 17 738.8
<i>m</i>	$mD_4'$	$mD_3'$	$mD_2'$	$mD_1'$	$mD_5''$	$mD_6''$
3	( $m^6D_4'$ ) 17 994.0	( $m^6D_3'$ ) 17 883.8	( $m^6D_2'$ ) 18 004.8	( $m^6D_1'$ ) 18 148.0	( $m^6D_5''$ ) 12 717.7	( $m^6D_6''$ ) 12 719.4
<i>m</i>	$mD_3''$	$mD_2''$	$mD_1''$	$mD_5'''$	$mD_4'''$	$mD_3'''$
3	( $m^6D_3''$ ) 12 722.0	( $m^6D_2''$ ) 12 725.5	( $m^6D_1''$ ) 12 730.2	( $m^6D_5'''$ ) 11 619.5	( $m^6D_4'''$ ) 11 636.5	( $m^6D_3'''$ ) 11 666.5
<i>m</i>	$mF_6$	$mF_5$	$mF_4$	$mF_3$	$mF_2$	$mF_1$
4	( $m^6F_6$ ) 16 264.5	( $m^6F_5$ ) 16 293.0	( $m^6F_4$ ) 16 342.0	( $m^6F_3$ ) 16 413.3	( $m^6F_2$ ) 16 508.9	( $m^6F_1$ ) 16 624.2

## Octet system

<i>m</i>	2	3	4	5	<i>m</i>	3
$ms$ ( $m^8S_4$ )	20 506.1	9 779.9	5 757.4	3 793.1	$md_5$ ( $m^8D_2$ )	13 231.3
$n^*$	2.314	3.346	4.365	5.379	$n^*$	2.880
$mp_2$ ( $m^8P_2$ )	41 535.0		7 448.5		$md_4$ ( $m^8D_3$ )	13 230.4
$n^*$	1.625		3.858		$n^*$	2.880
$mp_2$ ( $m^8P_4$ )	41 405.8		7 441.1		$md_3$ ( $m^8D_4$ )	13 229.1
$n^*$	1.628		3.856		$n^*$	2.880
$mp_1$ ( $m^8P_3$ )	41 232.1	13 956.1	7 431.6	4 675.4	$md_2$ ( $m^8D_5$ )	13 227.3
$n^*$	1.631	2.804	3.843	4.844	$n^*$	2.880
<i>m</i>	3	4	5	6		
$md_1$ ( $m^8D_6$ )	13 224.9	7 234.7	4 561.8	3 145.3		
$n^*$	2.980	3.894	4.904	5.907		
$mf$ ( $m^8F_1$ )		6 962.9	4 438.3			
$n^*$		3.969	4.973			

$$\parallel 2P_1''' = 9 838.4.$$

$$\nabla 3D_2''' = 11 711.5; 3D_1''' = 11 769.6.$$

## Mn II (2, 194)

## Mn III (95).

Mo  $Z = 42$ .  $N_{Mo} = 109 736.5$ .

Mo I (48, 52, 193, 325). Terms and limits (136);  $mP$ -terms are inverse; here (') and (') do not indicate terms are anomalous. (Limits calculated by Catalán (48, 52) differ from those used here.)

## Quintet system

<i>m</i>	2	3	4	<i>m</i>	3
$ms$ ( $m^5S_2$ )	48 792.2	18 720.1	9 455.3	$md_5$ ( $m^5D_0$ )	48 594.6
$n^*$	1.500	2.421	3.406	$md_4$ ( $m^5D_1$ )	48 417.6
$mp_2$ ( $m^5P_1$ )	30 636.9			$md_3$ ( $m^5D_2$ )	48 106.1
$mp_2$ ( $m^5P_3$ )	30 723.8			$md_2$ ( $m^5D_3$ )	47 702.0
$mp_1$ ( $m^5P_2$ )	30 845.3			$md_1$ ( $m^5D_4$ )	47 214.3
$3D_5'$ ( $3^5D_5'$ )	$3D_4'$ ( $3^5D_4'$ )	$3D_3'$ ( $3^5D_3'$ )	$3D_2'$ ( $3^5D_2'$ )	$3D_1'$ ( $3^5D_1'$ )	
26 908.2	26 661.8	26 261.4	25 605.5	24 479.4	
$3D_5''$ ( $3^5D_5''$ )	$3D_4''$ ( $3^5D_4''$ )	$3D_3''$ ( $3^5D_3''$ )	$3D_2''$ ( $3^5D_2''$ )	$3D_1''$ ( $3^5D_1''$ )	
22 460.4	22 267.4	21 981.3	21 592.1	21 137.6	

## Septet system

<i>m</i>	1	2	<i>m</i>	2	3
$ms$ ( $m^7S_3$ )	59 560.4	19 885.0	$mp_1'$ ( $m^7P_4'$ )	27 647.0	
$n; n^*$	5; 1.357	2.349	$md_5$ ( $m^7D_1$ )		14 624.7
$mp_2$ ( $m^7P_2$ )		33 946.1	$md_4$ ( $m^7D_2$ )		14 620.0
$mp_2$ ( $m^7P_4$ )		33 688.6	$md_3$ ( $m^7D_3$ )		14 613.1
$mp_1$ ( $m^7P_3$ )		33 239.9	$md_2$ ( $m^7D_4$ )		14 603.3
$mp_2'$ ( $m^7P_2'$ )		28 260.4	$md_1$ ( $m^7D_5$ )		14 590.5
$mp_2'$ ( $m^7P_4'$ )		28 027.0			

## Mo II (193, 325).

N  $Z = 7$ .  $N_N = 109 732.9$ .

N I (123, 139, 140, 249).

N II (22, 59, 84, 137, 249). Fowler (81) gives relative values for a singlet and a triplet system.

N III (22).

Na  $Z = 11$ .  $N_{Na} = 109 734.5$ .

Na I (15, 64, 127, 148, 163, 221, 224, 258, 263, 328). Limits (76).

<i>m</i>	1	2	3	4	5	6
$ms$ ( $m^2S_1$ )	41 449.0	15 709.5	8 248.3	5 077.3	3 437.3	2 480.7
$n; n^*$	3; 1.626	2.643	3.647	4.649	5.650	6.651
$mp_2$ ( $m^2P_1$ )		24 492.8	11 181.6	6 408.8	4 152.8	2 908.9
$n; n^*$		3; 2.116	3.133	4.138	5.140	6.141
$mp_1$ ( $m^2P_2$ )		24 475.7	11 176.1	6 406.3	4 151.3	2 907.5
$n; n^*$		3; 2.117	3.133	4.139	5.141	6.143
$md$ ( $m^2D$ )			12 276.2	6 900.4	4 412.5	3 061.9
$n; n^*$			3; 2.990	3.988	4.987	5.987
$mf$ ( $m^2F$ )				6 860.4	4 390.4	3 041.5
$n; n^*$				4; 3.999	5.000	6.006
$mg$ ( $m^2G$ )					4 389.8	
$n; n^*$					5; 5.000	
$mh$ ( $m^2H$ )						3 046.3
$n; n^*$						6; 6.002

<i>m</i>	7	8	9	10	11	12
$ms$ ( $m^3S_1$ )	1 874.5	1 466.0	1 175.5	966.1	804.4	679.5
$n^*$	7.651	8.652	9.662			
$mp_2'$ ( $m^3P_1$ )	2 150.7	1 655.4				
$n^*$	7.143	8.142				
$mp_1$ ( $m^3P_2$ )	2 149.8	1 654.1	1 312.3	1 065.9	883.4	743.3
$n^*$	7.144	8.145	9.145	10.147		
$md$ ( $m^3D$ )	2 248.6	1 720.9	1 357.2	1 098.7	907.1	761.7
$n^*$	6.986	7.986	8.992	9.994		

<i>m</i>	13	14	15	16	17	18
$mp_1$ ( $m^3P_2$ )	634.9	548.1	478.6	421.1	373.9	333.5
$md$ ( $m^3D$ )	647.7	559.0	491			

<i>m</i>	19	20	21	22	23	24
$mp_1$ ( $m^3P_2$ )	299.5	270.3	245.1	223.4	204.7	187.9

<i>m</i>	25	26	27	28	29	30
$mp_1$ ( $m^3P_2$ )	173.3	160.3	148.1	137.9	128.7	120.3

<i>m</i>	31	32	33	34	35	36
$mp_1$ ( $m^3P_2$ )	112.8	106.1	99.9	94.2	89.0	84.2

<i>m</i>	37	38	39	40	41	42
$mp_1$ ( $m^3P_2$ )	79.7	75.5	71.7	68.1	64.9	61.9

<i>m</i>	43	44	45	46	47	48
$mp_1$ ( $m^3P_2$ )	59.0	56.3	53.8	51.5	49.4	47.3

<i>m</i>	49	50	51	52	53	54
$mp_1$ ( $m^3P_2$ )	45.5	43.6	41.9	40.3	38.8	37.1

<i>m</i>	55	56	57	58
$mp_1$ ( $m^3P_2$ )	36.1	35.0	34.4	33.8

## Na II (89).

Nb  $Z = 41$ ; see Cb.

Ne  $Z = 10$ .  $N_{Ne} = 109 734.2$ . Ne I has 2 systems: "Normal" and "Displaced;" actually, both are equally normal. The term values for normal state (173 918 and 173 918 + 781) correspond to the  $L_{\alpha}$  and  $L_{\alpha}$ -X-ray levels; ionization potentials = 21.466 and 21.562 volts.

Ne I—P = Paschen's original notation, R-S = Russell-Saunders notation. Term values from Paschen (229, 230) who states that for some sequences the term value is  $A + \frac{N_{Ne}}{n^2}$ .

P R-S†	A	Normal terms				
<i>m</i>		2	3	4	5	6
$ms_4$ $ms_1$		39 470.2	(15 141.5)†	8 016.7	4 962.1	3 372.4
$n; n^*$		3; 1.668	2.692	3.700	4.702	5.765
$ms_5$ $ms_2$		39 887.6	(15 332.2)†	8 101.3	5 004.8	3 396.7
$n; n^*$		3; 1.658	2.675	3.681	4.683	5.684
$mp_2$ $mp_0$	40.0‡	173 918‡	23 012.0	10 528.1	6 062.1	3 952.7
$n; n^*$		2; 0.794	2.183	3.229	4.255	5.269



Ne I.—(Continued)

P R-S† m	A	Normal terms				
		2	3	4	5	6
$mp_1 mP_{1a}$	10‡	23 807.9	10 916.8	6 289.8	4 089.9	
$n; n^*$		3; 2.147	3.171	4.176	5.179	
$mp_{10} mP_{1b}$		25 671.7	11 411.5	6 479.9	4 181.3	
$n; n^*$		3; 2.067	3.101	4.115	5.123	
$mp_6 mP_{2a}$		23 613.6	10 891.0	6 280.7	4 085.6	
$n; n^*$		3; 2.156	3.174	4.180	5.182	
$mp_8 mP_{2b}$		24 105.2	11 030.3	6 338.1	4 114.7	
$n; n^*$		3; 2.133	3.154	4.161	5.164	
$mp_9 mP_3$		24 272.4	11 098.7	6 370.3	4 132.3	
$n; n^*$		3; 2.126	3.144	4.151	5.153	
$md_6 mD_0$		12 419.9	6 961.8	4 446.4	3 081.2	
$n; n^*$		3; 2.973	3.970	4.968	5.968	
$md_2 mD_{1a}$		12 292.9	6 902.5	4 412.4	3 061.5	
$n; n^*$		3; 2.988	3.987	4.988	5.988	
$md_5 mD_{1b}$		12 405.2	6 954.1	4 441.0	3 078.1	
$n; n^*$		3; 2.974	3.972	4.971	5.971	
$md_1' mD_{2a}$		12 229.8	6 881.9	4 403.1	3 056.6	
$n; n^*$		3; 2.995	3.993	4.992	5.992	
$md_3 mD_{2b}$		12 322.3	6 917.9	4 420.9	3 066.5	
$n; n^*$		3; 2.984	3.983	4.983	5.983	
$md_1' mD_{3a}$		12 228.1	6 880.8	4 402.6	3 056.2	
$n; n^*$		3; 2.996	3.994	4.993	5.992	
$md_4 mD_{3b}$		12 337.3	6 928.4	4 427.1	3 070.5	
$n; n^*$		3; 2.983	3.979	4.979	5.979	
$md_4' mD_4$		12 339.2	6 929.5	4 427.8	3 071.0	
$n; n^*$		3; 2.982	3.979	4.979	5.978	

m	7	8	9	10	11	12	13
$ms_4 mS_1$	2 440.0	1 848.5	1 447.6	1 164.9	957.1	800.7	
$n^*$	6.706	7.705	8.707	9.706			
$ms_5 mS_2$	2 456.1	1 858.1	1 454.1	1 169.6	960.9	803.4	
$n^*$	6.684	7.685	8.688	9.687			
$mp_2 mP_0$	2 780.6		1 602.1				
$n^*$	6.281		8.277				
$mp_7 mP_{1a}$	2 871.4	2 126.2	1 638.0	1 299.2	1 057.5		
$n^*$	6.181	7.184	8.185	9.191	10.187		
$mp_{10} mP_{1b}$	2 920.1	2 156.5					
$n^*$	6.130	7.134					
$mp_6 mP_{2a}$	2 869.2	2 126.2	1 638.0	1 299.2	1 057.5		
$n^*$	6.184	7.184	8.185	9.191	10.187		
$mp_8 mP_{2b}$	2 885.8	2 137.8	1 642.6				
$n^*$	6.166	7.165	8.173				
$mp_9 mP_3$	2 896.5	2 142.4	1 647.2	1 306.2			
$n^*$	6.154	7.157	8.162	9.166			
$md_6 mD_0$	2 260.3	1 729.1	1 364.5	1 104.9	912.0		
$n^*$	6.968	7.966	8.968	9.966			
$md_2 mD_{1a}$	2 246.6	1 720.3	1 358.6	1 100.2			
$n^*$	6.989	7.987	8.989	9.987			
$md_5 mD_{1b}$	2 257.5	1 727.6	1 363.5	1 104.0	911.5	765.8	651.9
$n^*$	6.972	7.970	8.971	9.970			
$md_1' mD_{2a}$	2 244.2	1 718.4	1 357.3	1 099.2	908.5	763.3	
$n^*$	6.993	7.992	8.992	9.992			
$md_3 mD_{2b}$	2 248.1	1 722.7	1 360.1	1 101.5	909.4	764.3	649.3
$n^*$	6.987	7.982	8.983	9.981			
$md_1' mD_{3a}$	2 243.9	1 718.2	1 357.2	1 099.2	908.2	762.9	646.5
$n^*$	6.993	7.992	8.992	9.992			
$md_4 mD_{3b}$	2 253.7	1 724.2	1 361.4	1 102.2	910.6	765.0	651.3
$n^*$	6.978	7.978	8.978	9.978			
$md_4' mD_4$	2 254.0	1 724.3	1 361.6	1 102.3	910.6	765.0	651.4
$n^*$	6.978	7.978	8.978	9.978			

P R-S m	A	Anomalous terms¶ (Ne I)				
		2	3	4	5	6
$ms_3 mS_0$	780.8	39 110.8	(14 651.9)†	7 323.1	4 223.5	2 616.6
$n; n^*$		3; (1.658)	(2.666)	(3.680)	(4.683)	(5.683)
$ms_2 mS_1$	781.3	38 040.7	(14 506.5)†	7 273.0	4 201.8	2 605.4
$n; n^*$		3; (1.681)	(2.679)	(3.692)	(4.693)	(5.693)
$mp_1 mP_0$	730.0**	173 918	20 958.7	9 643.5	5 342.4	3 240.0
$n; n^*$		2; (0.793)	(2.247)	(3.244)	(4.233)	(5.223)
$mp_2 mP_{1a}$	763.0**		22 891.0	10 221.7	5 570.8	3 351.0
$n; n^*$			3; (2.153)	(3.158)	(4.156)	(5.155)
$mp_3 mP_{1b}$	783.4		23 157.3	10 272.1	5 573.9	3 344.5
$n; n^*$			3; (2.141)	(3.151)	(4.155)	(5.157)
$mp_4 mP_2$	780.4		23 070.9	10 220.8	5 550.7	3 332.2
$n; n^*$			3; (2.145)	(3.158)	(4.163)	(5.165)
$ms_1' mD_1^A$	780.6		11 493.8	6 121.7	3 633.4	2 284.6
$n; n^*$			3; (2.990)	(3.987)	(4.986)	(5.983)

Ne I.—(Continued)

P R-S m	A	Anomalous terms¶ (Ne I)					
		2	3	4	5	6	
$ms_1'' mD_{2a}'$	780.5		11 509.5	6 132.5	3 640.1	2 287.3	
$n; n^*$			3; (2.988)	(3.984)	(4.982)	(5.981)	
$ms_1''' mD_{2b}'$	780.3		11 520.8	6 134.5	3 640.5	2 289.5	
$n; n^*$			3; (2.987)	(3.983)	(4.982)	(5.979)	
$ms_1''' mD_3'$	780.4		11 519.3	6 133.6	3 639.8	2 287.0	
$n; n^*$			3; (2.987)	(3.984)	(4.983)	(5.981)	
m		7	8	9	10	11	12
$ms_2 mS_0'$		1 675.1	1 077.3	674.2	389.5		
$n^*$		(6.684)	(7.685)	(8.684)	(9.683)		
$ms_2 mS_1'$		1 667.7	1 072.5	670.0	386.2		
$n^*$		(6.695)	(7.695)	(8.697)	(9.696)		
$mp_1 mP_0'$		2 016.0	1 264.3	747.9	422.9	232.8	115.4
$n^*$		(6.263)	(7.324)	(8.472)	(9.447)	(10.404)	
$mp_2 mP_{1a}'$		2 126.2					
$n^*$		(6.143)					
$mp_5 mP_{1b}'$		2 107.1	1 355.8	864.0			
$n^*$		(6.163)	(7.166)	(8.168)			
$mp_4 mP_2'$		2 101.4	1 356.0				
$n^*$		(6.169)	(7.166)				
$ms_1' mD_1'$		1 468.4	940.4	578.6	319.9	128.7	
$n^*$		(6.985)	(7.985)	(8.984)	(9.984)		
$ms_1'' mD_{2a}'$		1 471.0	942.3	580.0	321.0	129.1	
$n^*$		(6.981)	(7.980)	(8.980)	(9.979)		
$ms_1''' mD_{2b}'$		1 471.5	942.3	579.9	320.9	129.1	
$n^*$		(6.980)	(7.980)	(8.980)	(9.979)		
$ms_1''' mD_3'$		1 470.8	942.2	579.9	320.9	129.1	
$n^*$		(6.981)	(7.980)	(8.980)	(9.979)		

† Lande (151) has given  $j$ -values for all terms, and has shown (152) that each system may be regarded as compounded of two; the normal of a triplet and a quintet, and the anomalous of a singlet and a triplet. This resolution can not always be uniquely effected, and this type of resolution is not the only one possible (117), hence the upper index of the R-S notation has been omitted and the 2 terms of same lower index are distinguished (153) by  $a$  and  $b$ ,  $a$  denoting the smaller.

‡ Calculated; not based on observed lines.

§ Adding  $A$  makes only a little improvement:  $A$  not considered in computing  $n^*$ .

|| From (172).

¶ Grotrian (112) claims these correspond to a residue which differs from that for normal terms by  $781 \text{ cm}^{-1}$  in energy level. Here all terms (normal and anomalous) are reckoned from same zero level, but  $n^*$  is calculated from the real term value, which for an anomalous term is  $(781 + \text{tabulated value})$ ; the values of  $n^*$  which do not correspond to the tabulated term values are placed in ( ).

\*\* This sequence does not follow the formula closely;  $A$  could as well be taken as 781.

Ne II (38, 39, 40, 134, 260).

Ni Z = 28.  $N_{Ni} = 109 736.1$ .

Ni I (10, 12, 183, 318). Ni II (287).

O Z = 8,  $N_O = 109 733.4$ .

O I (221, 251). Terms:  $2P$  (17, 121), others (76).  $2P$ -terms are inverse.

Triplet system

m	1	2	3	4	5	6
$mS (m^3S_1)$		33 043.3	13 612.5	7 425.6	4 672.8	3 210.2
$n; n^*$		3; 1.823	2.840	3.843	4.846	5.847
$mp_1 (m^3P_0)$		109 607				
$n; n^*$		2; 1.001				
$mp_2 (m^3P_1)$		109 674				
$n; n^*$		2; 1.000				
$mp_1 (m^3P_2)$		109 833	21 207.2	10 157.5	5 968.6	
$n; n^*$		2; 1.000	2.285	3.286	4.288	
$mD (m^3D)$			12 350.0	6 929.9	4 429.2	3 072.3
$n; n^*$			3; 2.981	3.981	4.978	5.977
		7	8	9	10	
$mS (m^3S_1)$		2 340.9	1 780.3	1 401.7	1 130.6	
$n^*$		6.847	7.851	8.849	9.851	
$mD (m^3D)$		2 255.4	1 721.4	1 360.3	1 103.7	
$n^*$		6.975	7.984	8.982	9.971	



## O I.—(Continued)

## Quintet system

m	1	2	3	4	5	6
ms ( $m^3S_1$ )		36 069.0	14 358.5	7 720.8	4 817.9	3 291.9
n; n*		3; 1.745	2.762	3.770	4.773	5.773
mp <sub>1</sub> ( $m^3P_1$ )		23 211.9	10 744.3			
n; n*		3; 2.174	3.193			
mp <sub>2</sub> ( $m^3P_2$ )		23 209.2	10 743.7			
n; n*		3; 2.174	3.193			
mp <sub>1</sub> ( $m^3P_2$ )		23 205.8	10 742.5			
n; n*		3; 2.175	3.192			
md ( $m^3D$ )			12 417.3	6 971.7	4 451.5	3 085.7
n; n*			3; 2.973	3.966	4.965	5.963
m	7	8	9	10		
ms ( $m^3S_1$ )	2 391.6	1 815.7	1' 425.1			
n*	6.774	7.774	8.775			
md ( $m^3D$ )	2 263.9	1 731.4	1 367.1	1 106.1		
n*	6.962	7.961	8.963	9.961		

O II (22, 29, 60, 61, 82, 85, 207, 255).

O III (22, 83, 208, 209, 210, 211).

O IV (22). O V (30). O VI (30).

Os Z = 76.  $N_{Os} = 109\,736.8$ . Os I (197).P Z = 15.  $N_P = 109\,735.2$ . P I (262). P II (23).

P III (24, 213). Spectrum analogous to that of Al I.

m	2	3	m	3	4
ms ( $m^3S_1$ )	125 497.8	67 292.8	md <sub>1</sub> ( $m^3D_1$ )	126 461.4	
n; n*	4; 2.818	3.832	n; n*	3; 2.795	
mp <sub>1</sub> ( $m^3P_1$ )	243 332.1	101 957.8	md <sub>1</sub> ( $m^3D_2$ )	126 450.0	70 904.5
n; n*	3; 2.014	3.112	n; n*	3; 2.795	3.732
mp <sub>1</sub> ( $m^3P_2$ )	242 772.5	101 821.2			
n; n*	3; 2.016	3.115			

P IV (27). Spectrum analogous to that of Mg I. Only triplet system is known.

## Triplet system

m	2	3	m	3	4
ms ( $m^3S_1$ )	187 687.9	105 479.2	md <sub>1</sub> ( $m^3D_1$ )		121 344.0
n; n*	4; 3.068	4.081	n*		3.804
mp <sub>1</sub> ( $m^3P_1$ )	346 661.4	158 032.4	md <sub>1</sub> ( $m^3D_2$ )		121 338.4
n; n*	3; 2.261	3.332	n*		3.804
mp <sub>1</sub> ( $m^3P_2$ )	346 432.8	157 973.7	md <sub>1</sub> ( $m^3D_3$ )	225 185.0	121 330.7
n; n*	3; 2.261	3.334	n; n*	3; 2.793	3.804
mp <sub>1</sub> ( $m^3P_2$ )	345 964.9	157 825.3			
n; n*	3; 2.263	3.335			

P V (26). Spectrum analogous to that of Na I.

m	1	2	3	4	5	6
ms ( $m^3S_1$ )	524 491.2	251 540.7	147 858.7			
n; n*	3; 2.287	3.303	4.307			
mp <sub>1</sub> ( $m^3P_1$ )		435 841.8	220 339.0			
n; n*		3; 2.502	3.528			
mp <sub>1</sub> ( $m^3P_2$ )		435 046.9	220 055.1			
n; n*		3; 2.511	3.531			
md ( $m^3D$ )			320 295.0	179 101.1		
n; n*			3; 2.927	3.913		
mf ( $m^3F$ )				171 909.4	110 036.5	
n; n*				4; 3.995	4.994	
mg ( $m^3G$ )					109 818.4	76 278.5
n; n*					5; 4.998	5.997
mh ( $m^3H$ )						76 255.2
n; n*						6; 5.998

Pb Z = 82.  $N_{Pb} = 109\,736.8$ .Pb I (3, 101, 102, 182, 299, 305, 305.5, 308, 310); p- and d-notations are tentative; small changes in arrangement of d-terms have been made, and a new series of d-terms suggested; 3d<sub>3</sub> does not combine with 2p<sub>1</sub>.

j	m	2	3	4	5	6	7
1	ms	24 524.0	11 124.3	6 300.7	4 091.2	2 872.7	2 123.5†
	n; n*	7; 2.115	3.141	4.173	5.178	6.180	7.189
0	mp <sub>1</sub>	59 811.2					
	n*	1.354					
1	mp <sub>1</sub>	51 992.0					
	n*	1.453					

## Pb I.—(Continued)

j	m	2	2	4	5	6	7
2	mp <sub>2</sub>	49 180.8					
	n*	1.494					
2	mp <sub>1</sub>	38 353.2					
	n*	1.691					
2	md <sub>1</sub>		14 367.7	7 709.1	4 808.0	3 274.9	2 389.9†
	n*		2.763	3.773	4.778	5.789	6.776
2	md <sub>2</sub>		13 750.2	7 501.1	4 728.8	3 246.7	2 371
	n*		2.825	3.825	4.818	5.814	6.803
1	md <sub>2</sub>		13 742.7	7 311.8	4 652.7	3 210.7	2 344‡
	n*		2.826	3.874	4.856	5.846	6.842
3	md <sub>1</sub>		13 482.3	7 399.3			
	n*		2.853	3.851			

† 8s = 1628, n\* = 8.210. ‡ 8d<sub>1</sub> = 1812, n\* = 7.782. § 8d<sub>2</sub> = 1786, n\* = 7.839; 9d<sub>2</sub> = 1400, n\* = 8.854.

Pb II (103).

Pd Z = 46.  $N_{Pd} = 109\,736.5$ .

Pd I (7, 11, 179, 180, 197). Pd II (180).

Pt Z = 78.  $N_{Pt} = 109\,736.8$ . Pt I (175.5, 197).Ra Z = 88.  $N_{Ra} = 109\,736.8$ .

Ra I. Spectrum not yet analyzed.

Ra II (90, 244). Terms (76) calculated by (119).

m	1	2	3	4
ms ( $m^3S_1$ )	82 862.1	39 457.0		
n; n*	7; 2.301	3.335		
mp <sub>1</sub> ( $m^3P_1$ )		61 510.4		
n; n*		7; 2.671		
mp <sub>1</sub> ( $m^3P_2$ )		56 653.2		
n; n*		7; 2.784		
md <sub>1</sub> ( $m^3D_1$ )				34 118.1
n; n*				7; 3.587
md <sub>1</sub> ( $m^3D_2$ )				33 621.8
n; n*				7; 3.613

Rb Z = 37.  $N_{Rb} = 109\,736.4$ .

Rb I (15, 127, 163, 221, 224, 238, 239, 258, 263). Term values (76).

m	1	2	3	4	5	6
ms ( $m^3S_1$ )	33 689.1	13 557.9	7 378.1	4 642.9	3 191.2	2 328.5
n; n*	5; 1.805	2.846	3.856	4.862	5.864	6.865
mp <sub>1</sub> ( $m^3P_1$ )		21 110.2	9 974.1	5 854.2	3 854.8	2 729.9
n; n*		5; 2.280	3.317	4.329	5.336	6.340
mp <sub>1</sub> ( $m^3P_2$ )		20 872.6	9 896.6	5 819.2	3 835.5	2 719.6
n; n*		5; 2.293	3.331	4.342	5.349	6.351
md <sub>1</sub> ( $m^3D_1$ )			14 334.3	7 988.9	5 002.4	3 409.6
n; n*			4; 2.767	3.706	4.684	5.673
md <sub>1</sub> ( $m^3D_2$ )				7 985.9	5 000.2	3 407.7
n; n*				5; 3.707	4.685	5.675
mf ( $m^3F$ )				6 897.6	4 418.2	3 068.0
n; n*				4; 3.989	4.984	5.981
mg ( $m^3G$ )					4 389.9	
n; n*					5; 5.000	
mh ( $m^3H$ )						3 044.0
n; n*						6; 6.004

m	7	8	9	10	11	12
ms ( $m^3S_1$ )	1 773.8	1 397.4				
n*	7.865	8.862				
mp <sub>1</sub> ( $m^3P_1$ )	2 033.8					
n*	7.345					
mp <sub>1</sub> ( $m^3P_2$ )	2 028.2	1 573.3	1 254.8	1 024.2	849.3	718.0
n*	7.356	8.351	9.353	10.351		
md <sub>1</sub> ( $m^3D_1$ )	2 468.2	1 868.8	1 464.6	(1 182.7)		
n*	8.668	7.663	8.658	9.653		
md <sub>1</sub> ( $m^3D_2$ )	2 467.0	1 867.6	1 463.5	1 176.7		
n*	8.669	7.665	8.660	9.657		
mf ( $m^3F$ )	2 252.4					
n*	6.980					

m	13	14	15	16	17	18
mp <sub>1</sub> ( $m^3P_2$ )	614.6	531.7	464.1	409.7	363.6	325.3
m	19	20	21	22	23	24
mp <sub>1</sub> ( $m^3P_2$ )	292.0	265.2	240.8	219.2	201.7	186.0
m	25	26	27	28	29	30
mp <sub>1</sub> ( $m^3P_2$ )	170.6	157.5	146.3	136.2	127.1	119.1†

† 31p<sub>1</sub> = 111.1.



Rh  $Z = 45$ .  $N_{Rh} = 109\,736.5$ .

Rh I (197, 292, 293).

Ru  $Z = 44$ .  $N_{Ru} = 109\,736.5$ .

Ru I (195, 196, 197, 289, 290).

S  $Z = 16$ .  $N_S = 109\,735.2$ .

S I (124, 251). Terms: triplet (17) from measurements (120); others (76), 1s is from measurements of (201).

## Triplet system

$m$	$mS$ ( $m^3S_1$ ) $n; n^*$	$mP_2$ ( $m^3P_0$ ) $n; n^*$	$mP_2$ ( $m^3P_1$ ) $n; n^*$	$mP_1$ ( $m^3P_2$ ) $n; n^*$	$mD$ ( $m^3D$ ) $n; n^*$
2	28 229 4; 1.972	82 982 3; 1.160	83 156 3; 1.149	83 554 3; 1.146	
3	12 204 2.999				15 665 3; 2.648
4	6 835 4.006	(9 288) 3.437	(9 290) 3.437	(9 291) 3.437	

## Quintet system

$m$	2	3	$m$	$ms$ ( $m^5S_2$ ) $n^*$	$md$ ( $m^5D$ ) $n; n^*$
$ms$ ( $m^5S_2$ ) $n; n^*$	30 936.9 4; 1.883		5	4 502.5 4.936	5 290.2 5; 4.554
$mp_2$ ( $m^5P_1$ ) $n; n^*$	20 114.7 4; 2.336	9 649.5 3.372	6	3 111.6 5.939	3 568.3 5.546
$mp_2$ ( $m^5P_2$ ) $n; n^*$	20 103.4 4; 2.337	9 645.9 3.373	7	2 278.9 6.940	2 565.7 6.539
$mp_1$ ( $m^5P_3$ ) $n; n^*$	20 085.5 4; 2.338	9 639.9 3.374	8	1 741.1 7.939	1 931.8† 7.536

† For  $m = 9$ ,  $md = 1\,506.8$ ,  $n^* = 8.533$ ; for  $m = 10$ ,  $md = 1\,207.8$ ,  $n^* = 9.533$ .

S II, S III. Spectrum not yet analyzed.

S IV. (24, 213). Spectrum analogous to that of Al I.

$m$	2	3	$m$	3	4
$ms$ ( $m^3S_1$ ) $n; n^*$	200 109.2 4; 2.963	110 531.0 3.985	$md_2$ ( $m^3D_2$ ) $n; n^*$	229 414.3 3; 2.766	
$mp_2$ ( $m^3P_1$ ) $n; n^*$	381 541.4 3; 2.145	168 034.0 3.233	$md_1$ ( $m^3D_3$ ) $n; n^*$	229 400.0 3; 2.766	126 151.6 3.731
$mp_1$ ( $m^3P_2$ ) $n; n^*$	380 591.2 3; 2.148	167 824.0 3.234			

S V (27). Spectrum analogous to that of Mg I. Only triplet system is known.

## Triplet system

$m$	2	3	$m$	2	3
$ms$ ( $m^3S_1$ ) $n; n^*$	273 075.0 4; 3.170		$mp_1$ ( $m^3P_2$ ) $n; n^*$	500 497.7 3; 2.341	235 191.6 3.416
$mp_2$ ( $m^3P_0$ ) $n; n^*$	501 618.2 3; 2.339	235 568.6 3.413	$md$ ( $m^3D$ ) $n; n^*$		349 700.0 3; 2.801
$mp_2$ ( $m^3P_1$ ) $n; n^*$	501 252.4 3; 2.340	235 480.7 3.413			

S VI (26). Spectrum analogous that of Na I.

$m$	1	2	3	4	5
$ms$ ( $m^3S_1$ ) $n; n^*$	710 264.2 3; 2.368	347 264.0 3.373			
$mp_2$ ( $m^3P_1$ ) $n; n^*$		604 398.2 3; 2.557	309 083.5 3.575		
$mp_1$ ( $m^3P_2$ ) $n; n^*$		603 131.1 3; 2.558	308 625.9 3.577		
$md_2$ ( $m^3D_2$ ) $n; n^*$			462 854.4 3; 2.921		
$md_1$ ( $m^3D_3$ ) $n; n^*$			462 818.2 3; 2.921		
$mf$ ( $m^3F$ ) $n; n^*$				247 612.1 4; 3.994	
$mg$ ( $m^3G$ ) $n; n^*$					158 159.5 5; 4.998

Sb  $Z = 51$ .  $N_{Sb} = 109\,736.6$  (248).Sc  $Z = 21$ .  $N_{Sc} = 109\,735.8$ .

Sc I (46, 50, 50.5, 58, 94, 100, 109, 186, 256)

Sc II (50.5, 186, 194, 237, 256).

Sc III (92).

Se  $Z = 34$ .  $N_{Se} = 109\,736.3$ .

Se I (177, 251). Terms (76). Only the quintet system is known.

$m$	1	2	3	4	5	6
$ms$ ( $m^5S_2$ ) $n; n^*$					4 449.1 5; 4.967	3 085.0 5.964
$mp_2$ ( $m^5P_1$ ) $n; n^*$		19 416.2 5; 2.377				
$mp_2$ ( $m^5P_2$ ) $n; n^*$		19 371.4 5; 2.380				
$mp_1$ ( $m^5P_3$ ) $n; n^*$		19 267.7 5; 2.386				
$md$ ( $m^5D$ ) $n; n^*$					5 112.5 5; 4.633	3 462.1 5.629

$m$	7	8	9	10	11
$ms$ ( $m^5S_2$ ) $n^*$	2 261.5 6.966	1 729.3 7.965			
$md$ ( $m^5D$ ) $n^*$	2 498.2 6.628	1 887.9 7.624	1 472.2 8.634	1 184.3 9.627	973.2

Si  $Z = 14$ .  $N_{Si} = 109\,735.0$ .

Si I (80). Si II (24, 79, 80). Si III (79, 80).

Si IV (80). Terms (77) corrected (26) to basis of  $N_{Si}$ .

$m$	1	2	3	4	5	6
$ms$ ( $m^3S_1$ ) $n; n^*$	364 109 3; 2.196	170 138 3.212	98 699 4.218			
$mp_2$ ( $m^3P_1$ ) $n; n^*$		292 822 3; 2.449	145 850 3.470	87 613 4.477		
$mp_1$ ( $m^3P_2$ ) $n; n^*$		292 362 3; 2.451	145 688 3.472	87 538 4.479		41 719† 6.487
$md$ ( $m^3D$ ) $n; n^*$			203 738 3; 2.936	114 109 3.922	72 627 4.916	
$mf$ ( $m^3F$ ) $n; n^*$	35 925 6.991	27 491† 7.992		109 987 4; 3.996	70 399 4.994	48 895 5.993
$mg$ ( $m^3G$ ) $n; n^*$	35 868 6.996				70 277 5; 4.999	48 813 5.997
$mh$ ( $m^3H$ ) $n; n^*$						48 797 6; 5.998

† From (178).

Sn  $Z = 50$ .  $N_{Sn} = 109\,736.6$ .Sn I (4, 110, 181, 299, 306).  $j$ -values (299).

$j$	$m$	2	3	4	5	6	7
1	$ms$ $n; n^*$	24 245 6; 2.127	10 936 3.168	6 135 4.229	4 021 5.223	2 856 6.198	2 129 7.180
0	$mp_2$ $n^*$	59 158 1.362					
1	$mp_2$ $n^*$	57 466 1.382					
2	$mp_1$ $n^*$	55 731 1.404					
?	$mX_2$ $n^*$	55 443 1.407					
2	$mX_2$ $n^*$	50 546 1.473					
0	$mX_1$ $n^*$	41 997 1.616					
†	$md_2$ $n^*$		15 015 2.704	8 147 3.670	5 146 4.618	3 466 5.626	2 499 6.627
‡	$md_2$ $n^*$		14 650 2.737	7 995 3.705		3 414 5.670	
§	$md_1$ $n^*$		14 583 2.743	7 405 3.850		3 351 5.723	

$j$	$m$	8	9	10	11
1	$ms$ $n^*$	1 633 8.197	1 303 9.178	1 059 10.180	873

†  $j_2 = 2$ ,  $j_1 = j_0 = 1$ . ‡  $j_2 = j_0 = 1$ ,  $j_1 = 2$ . §  $j_2 = j_1 = 3$ ,  $j_0 = 1$ .

Sn II (216, 217). Terms (110). Spectrum analogous to that of In I.

$m$	2	3	4	5
$ms$ ( $m^3S_1$ ) $n; n^*$	60 821 6; 2.686	33 000 3.646	20 293 4.650	
$mp_2$ ( $m^3P_1$ ) $n; n^*$	117 704 5; 1.931	46 213 3.081	24 980 4.191	
$mp_1$ ( $m^3P_2$ ) $n; n^*$	113 451 5; 1.966	45 329 3.111	24 623 4.221	
$md_2$ ( $m^3D_2$ ) $n; n^*$		46 301 5; 3.078	27 467 3.977	



## Sn II.—(Continued)

m	2	3	4	5
$md_1 (m^3D_1)$		45 658	27 360	17 857
n; n*		5; 3.100	4.006	4.968
$mf (m^3F)$			28 416	18 056
n; n*			4; 3.930	4.930

Sn III (241). Terms (110). Spectrum analogous to that of Cd I.

## Singlet system

m	1	2	3	m	4	5
$mS (m^1S_0)$	243 235			$mF (m^1F_3)$	61 475	39 611
n; n*	5; 2.016			n; n*	4; 4.006	4.994
$mP (m^1P_1)$		163 327	80 517	$mG (m^1G_4)$		39 133
n; n*		5; 2.459	3.502	n; n*		5; 5.024
$mD (m^1D_2)$			99 650			
n; n*			5; 3.148			

## Triplet system

m	2	3	m	3	4	5
$ms (m^3S_1)$	103 604		$md_1 (m^3D_1)$	101 404		
n; n*	5; 3.088		n; n*	5; 3.121		
$mp_2 (m^3P_2)$	189 691	83 302	$mf_2 (m^3F_2)$		63 937	
n; n*	5; 2.282	3.449	n; n*		4; 3.930	
$mp_1 (m^3P_1)$	188 044	83 026	$mf_1 (m^3F_1)$		63 900	
n; n*	5; 2.291	3.449	n; n*		4; 3.931	
$mp_1 (m^3P_2)$	184 011	81 802	$mf_1 (m^3F_4)$		63 802	
n; n*	5; 2.317	3.475	n; n*		4; 3.934	
$md_2 (m^3D_1)$		101 921	$mg (m^3G)$			39 158
n; n*		5; 3.113	n; n*			5; 5.000
$md_1 (m^3D_2)$		101 716				
n; n*		5; 3.116				

Sr Z = 38.  $N_{Sr} = 109 736.4$ .

Sr I (72, 128, 239, 259, 267). Terms: normal (271); anomalous (257).

## Singlet system

m	1	2	3	4	5	6
$mS (m^1S_0)$	45 925.6	15 334.5	7 481.6	4 873.1	3 329.6	2 412.8
n; n*	5; 1.546	2.676	3.830	4.746	5.741	6.744
$mP (m^1P_1)$		24 227.1	11 827.5	7 019.0	4 753.5	3 463.4
n; n*		5; 2.128	3.045	3.953	4.806	5.628
$mD (m^1D_2)$			25 776.3	11 110.0	6 192.4	4 093.7
n; n*			4; 2.063	3.143	4.209	5.177
$mf (m^1F_3)$				6 387.0	4 406.9	3 086.8
n; n*				(4) 4.146	4.991	5.968

† 13F = 648.1.

## Triplet system, normal terms

m	2	3	4	5	6	7
$ms (m^3S_1)$	16 886.8	8 500.9	5 163.2	3 473.7	2 498.0	1 882.0
n; n*	5; 2.549	3.591	4.610	5.620	6.629	7.636
$mp_2 (m^3P_2)$	31 608.0	12 109.8	6 525.0			
n; n*	5; 1.868	3.010	4.101			
$mp_1 (m^3P_1)$	31 421.1	12 068.4	6 510.2			
n; n*	5; 1.869	3.016	4.106			
$mp_1 (m^3P_2)$	31 026.8	11 963.6	6 479.1			
n; n*	5; 1.880	3.024	4.116			
$md_1 (m^3D_1)$		27 766.0	10 918.3	6 239.4	4 061.1	2 858.7
n; n*		4; 1.988	3.170	4.193	5.197	6.196
$md_2 (m^3D_2)$		27 706.4	10 903.8	6 234.5	4 056.5	2 855.1
n; n*		4; 1.991	3.172	4.195	5.200	6.199
$md_1 (m^3D_3)$		27 606.0	10 880.5	6 222.2	4 051.0	2 850.6
n; n*		4; 1.994	3.176	4.200	5.204	6.204
$mf_2 (m^3F_2)$			7 174.6	4 560.4	3 160.5	2 314.5
n; n*			4; 3.911	4.905	5.898	6.888
$mf_1 (m^3F_1)$			7 172.9	4 559.6	3 159.9	2 312.6
n; n*			4; 3.911	4.908	5.898	6.888
$mf_1 (m^3F_4)$			7 170.2	4 558.7	3 147.6	2 301.1
n; n*			4; 3.912	4.906	5.904	6.906

## Sr I. Triplet system, normal terms.—(Continued)

m	8	9	10	11	12	13
$ms (m^3S_1)$	1 467.7					
n*	8.647					
$md_2 (m^3D_1)$	2 123.7	1 641.7				
n*	7.189	8.176				
$md_2 (m^3D_2)$	2 120.5	1 638.4	1 307.0	1 065.4		
n*	7.194	8.184	9.163	10.149		
$md_1 (m^3D_3)$	2 116.4	1 634.0	1 300.3	1 060.5	881.5	†
n*	7.201	8.196	9.187	10.173		
$mf_1 (m^3F_4)$	1 753.5	1 380.5	1 115.3	919.7	769.6	651.2
n*	7.911	8.916	9.920			

## Triplet system, anomalous terms

m	2	3
$mp'_2 (m^3P'_2)$	10 731.8	1 399.8
$mp'_2 (m^3P'_1)$	10 525.5	1 329.6
$mp'_1 (m^3P'_2)$	10 250.7	1 195.9

† 14d<sub>1</sub> = 638.0, 15d<sub>1</sub> = 552.8.

Sr II (74, 75, 165, 244). Term values calculated from data (76) and 4f-limit (90); corrected to int. scale. Spectrum analogous to that of Rb I.

m	1	2	3	4	5	6
$ms (m^3S_1)$	88 854.7	41 118.2	23 891.1	15 614.8		
n; n*	5; 2.222	3.267	4.286	5.302		
$mp_2 (m^3P_1)$		65 139.5				
n; n*		5; 2.596				
$mp_1 (m^3P_2)$		64 338.0				
n; n*		5; 2.611				
$md_2 (m^3D_1)$			74 297.9	35 568.4	21 332.2	14 233.0
n; n*			4; 2.431	3.513	4.536	5.552
$md_1 (m^3D_2)$			74 017.8	35 482.8	21 292.1	14 211.7†
n; n*			4; 2.436	3.517	4.541	5.558
$mf (m^3F)$				27 862.6	17 798	12 314†
n; n*				4; 3.968	4.966	5.970

† For m = 7, md<sub>1</sub> = 10 195, n\* = 6.561; mf = 8998, n\* = 6.985.

Te Z = 52.  $N_{Te} = 109 736.6$ .

Te I (177).

Ti Z = 22.  $N_{Ti} = 109 735.9$ .

Ti I (50, 100, 142, 144).

Ti II (94, 194, 303).

Ti IV (92).

Tl Z = 81.  $N_{Tl} = 109 736.8$ .

Tl I (130, 222). Limits (76).

m	2	3	4	5	6	7
$ms (m^3S_1)$	22 786.7	10 518.3	6 098.2	3 968.2	2 808.9	2 085.0
n; n*	7; 2.196	3.230	4.248	5.259	6.260	7.254
$mp_2 (m^3P_1)$	49 264.2	15 104.6	7 895.9	4 883.3	3 324.9	2 410.4†
n; n*	6; 1.493	2.696	3.788	4.740	5.746	6.747
$mp_1 (m^3P_2)$	41 471.5	14 103.4	7 523.2	4 701.7	3 220.6	2 347.1
n; n*	6; 1.627	2.790	3.819	4.831	5.837	6.837
$md_2 (m^3D_1)$		13 146.2	7 252.8	4 591.6	3 165.8	2 314.1
n; n*		6; 2.889	3.889	4.888	5.887	6.886
$md_1 (m^3D_2)$		13 064.3	7 215.2	4 571.5	3 153.9	2 306.4
n; n*		6; 2.898	3.900	4.899	5.898	6.898
$mf (m^3F)$			6 945.8	4 440.7		2 244.9
n; n*			5; 3.976	4.978		6.988

m	8	9	10	11	12	13
$ms (m^3S_1)$	1 610.2	1 282.3	1 040.0	865.8	730.5	626.0‡
n*	8.866	9.861	10.872			
$mp_1 (m^3P_2)$	1 786.2	1 416	1 135	933	805	
n*	7.839	8.803	9.833			
$md_1 (m^3D_1)$	1 760.1	1 385.9	1 120.3	923.5	774.6	659.0
n*	7.866	8.898	9.897			

† 8p<sub>1</sub> = 1 821.6, n\* = 7.768.

‡ n from (180).

§ 14s = 536.5.

|| 14d<sub>1</sub> = 565.7, 15d<sub>1</sub> = 491.9.

V Z = 23.  $N_V = 109 735.9$

V I (13, 50, 53, 100, 155, 156, 185).

V II (189, 194).

V III (94).

V IV (93).



W Z = 74.  $N_W = 109\,736.8$ .

W I (158, 159).

Yt Z = 39.  $N_{Yt} = 109\,736.4$ .

Yt I (186, 193, 198).

Yt II (193, 237).

Yt III (32).

m	2	3	m	3	4
$ms (m^2S_1)$	157 822.9	78 572.6	$md_2 (m^2D_2)$	165 289.2	76 910.4
n; n*	5; 2.502	3.546	n; n*	4; 2.444	3.584
$mp_2 (m^2P_1)$	123 888.7		$md_1 (m^2D_3)$	164 565.8	76 711.4
n; n*	5; 2.823		n; n*	4; 2.450	3.588
$mp_1 (m^2P_2)$	122 335.0		$mf (m^2F)$		64 200.0
n; n*	5; 2.842		n; n*		4; 3.916

Zn Z = 30.  $N_{Zn} = 109\,736.2$ .

Zn I (90, 128, 131, 222, 223, 225, 227, 259, 264, 276, 277, 326).

Terms (76, 274). Not much difference between value of 2P-limits used here and those of Fues (90) when corrected to int. scale.

#### Singlet system

m	1	2	3	4	5	6
$mS (m^1S_0)$	75 766.8	19 978.7	9 729.5	5 763.7	3 812.5	2 709.4
n; n*	4; 1.204	2.343	3.358	4.363	5.365	6.364
$mP (m^1P_1)$		29 021.7	12 857.9	7 160.6	4 559.1	3 141.7†
n; n*		4; 1.044	2.921	3.914	4.906	5.910
$mD (m^1D_2)$			13 308.6	7 428.9	4 719.2	(3 276)
n; n*			4; 2.871	3.843	4.822	5.788

#### Triplet system

m	2	3	4	5	6	7
$ms (m^3S_1)$	22 094.4	10 334.4	6 019.7	3 943.2	2 780.5	2 068.2
n; n*	5; 2.228	3.259	4.269	5.276	6.281	7.285
$mp_2 (m^3P_0)$	43 455.0	14 519.4	7 695.8	4 789.2	3 270.2	2 375.9
n; n*	4; 1.589	2.749	3.776	4.787	5.793	6.796
$mp_1 (m^3P_1)$	43 265.0	14 492.7	7 686.0	4 784.5	3 267.6	2 374.0
n; n*	4; 1.592	2.752	3.779	4.790	5.795	6.799
$mp_1 (m^3P_2)$	42 876.3	14 436.5	7 664.9	4 774.2	3 262.0	2 370.3
n; n*	4; 1.599	2.757	3.783	4.795	5.800	6.805
$md_1 (m^3D_1)$		12 997.6	7 187.0			
n; n*		4; 2.905	3.908			
$md_2 (m^3D_2)$		12 994.2	7 185.9			
n; n*		4; 2.906	3.908			
$md_1 (m^3D_3)$		12 988.7	7 183.9	4 553.1	3 139.9	2 295.6
n; n*		4; 2.905	3.908	4.909	5.912	6.914
$mf (m^3F)$			6 931.3	(4 442.3)		
n; n*			4; 3.979	4.971		

† For  $m = 7$ ,  $mP = 2\,298.2$ ,  $n^* = 6.911$ ; for  $m = 8$ ,  $mP = 1\,755.5$ ,  $n^* = 7.907$ .

Zn II (261). Spectrum analogous to that of Cu I.

m	1	2	3	4	5	6
$ms (m^2S_1)$	144 890.2	56 454.4	30 393.9	19 011.6	13 014.2	9 468.1
n; n*	4; 1.741	2.788	3.800	4.805	5.808	6.809
$mp_2 (m^2P_1)$		96 410.1	43 525.4	25 002.4		
n; n*		4; 2.134	3.176	4.190		
$mp_1 (m^2P_2)$		95 536.5	43 280.3	24 931.6	16 219.0	
n; n*		4; 2.143	3.185	4.196	5.202	
$md_2 (m^2D_2)$			79 450.0†	47 982.2	26 922.4	17 261.3
n; n*			4; 2.350	3.025	4.038	5.043
$md_1 (m^2D_3)$			82 169.0†	47 931.4	26 898.2	17 248.3
n; n*			4; 2.311	3.026	4.040	5.045
$mf_2 (m^2F_3)$					17 681.1	12 287.3
n; n*					5; 4.983	5.977
$mf_1 (m^2F_4)$				27 628.0	17 691.7	12 252.1
n; n*				4; 3.986	4.981	5.985
$mg (m^2G)$						12 207.3
n; n*						6; 5.996

† Values of  $n^*$  show these do not belong to  $md$ -series. These and some of the pairs are inverse.

#### Zn II.—(Continued)

m	7	8	9	m	7	8
$md_2 (m^2D_2)$	12 010.2	8 839.0	(6 777.0)	$mf_1 (m^2F_4)$	9 002.0	6 885.1
n*	6.045	7.047	8.048	n*	6.983	7.986
$md_1 (m^2D_3)$	12 003.0	8 834.5	6 773.8	$mg (m^2G)$	8 968.1	
n*	6.047	7.049	8.050	n*	6.986	
$mf_2 (m^2F_3)$	8 999.2					
n*	6.984					

Zn III (161).

Zr Z = 40.  $N_{Zr} = 109\,736.4$ .

Zr I (143).

Zr II and Zr III (145).

Zr IV (32).

m	2	m	3	4
$ms (m^2S_1)$	238 545.9	$md_2 (m^2D_2)$	276 803.5	
n; n*	5; 2.713	n; n*	4; 2.527	
$mp_2 (m^2P_1)$	194 827.4	$md_1 (m^2D_3)$	275 553.3	
n; n*	5; 3.002	n; n*	4; 2.523	
$mp_1 (m^2P_2)$	192 344.4	$mf (m^2F)$		117 725.0
n; n*	5; 3.021	n; n*		4; 3.862

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- (320) Werner, in (21). (321) Werner, *58*, 116: 574; 25. (322) Werner, *58*, 118: 154; 26. (322.5) Werner, *Diss.*, Copenhagen, 1927. (323) Werner, University of Copenhagen, *O*. (324) Wiedemann, *8*, 33: 1041; 12. (325) Wilhelmy, *8*, 80: 305; 26. (326) Wolff, *8*, 42: 825; 13. (327) Wood, *3*, 44: 538; 22. (328) Wood and Fortrat, *21*, 43: 73; 16. (329) Zeeman, *63*, 14: 405; 13.



## STRUCTURES OF THE OPTICAL SPECTRA OF ATOMS

W. F. MEGGERS

(For compilation of our knowledge in 1922 of regularities in line spectra, see (38, 59, 105); for atomic structure and its relation to spectra, see Vol. I, p. 47, and Emission of X-rays, Vol. VI; for term values for series in atomic spectra, see p. 392; for structure of band spectra of compounds, see p. 409.)

The most important features of any optical system may be represented by the values of two quantum numbers  $l$  and  $r$ ;  $l$  indicating the type of term corresponding to the lowest atomic energy (normal or unexcited state), and  $r$  the maximum multi-

plicity of sub-levels occurring in the spectral terms. The types commonly denoted by  $S, P, D, F, G, \dots$  correspond to  $l = 0, 1, 2, 3, 4, \dots$ . In the following table are given all the values of  $l$  and  $r$  which are now (February, 1928) definitely known. Presented for spectra of atoms in the order of increasing atomic number ( $Z$ ), these data illustrate the *alternation* and *displacement* laws of spectroscopy as well as periodic regularities in the values of  $l$  and  $r$ .

TABLE 1.—VALUES OF THE QUANTUM NUMBERS ( $l, r$ ) FOR THE OPTICAL SPECTRA OF ATOMS

$Z$  = atomic number; values of  $l$  and  $r$  are given in the form  $r^l$  for the spectra of normal atoms ( $I$ ) and of atoms in successive stages of ionization ( $II, III, \dots$ ), the values of  $l$  being those for the term of zero energy (normal state). There are no data for  $Z = 43, 59$  to  $73, 75, 84$  to  $87$ , and  $89$  to  $92$ , inclusive. The sources from which the data were obtained are indicated in the paragraph following the table. The symbols of the elements are there arranged alphabetically, and the atomic numbers are printed as subscripts.

$Z$	(1)	$I$	$II$	$III$	$IV$	$V$	$Z$	(1)	$I$	$II$	$III$	$IV$	$V$	$Z$	(1)	$I$	$II$	$III$	$IV$	$V$
1	H	2					24*	Cr	3, 5, 7 <sup>0</sup>	2, 4, 6	5		3	47	Ag	2 <sup>0</sup>	1, 3			
2	He	1, 3 <sup>0</sup>	2				25*	Mn	4, 6 <sup>0</sup> , 8	5, 7 <sup>0</sup>	6			48	Cd	1 <sup>0</sup> , 3	2 <sup>0</sup>			
3	Li	2 <sup>0</sup>	3(?)				26	Fe	3, 5 <sup>2</sup> , 7	4, 6 <sup>2</sup>				49	In	2 <sup>1</sup>	3	2		
4	Be	3 <sup>0</sup>	2				27	Co	2, 4 <sup>3</sup> , 6	3, 5				50	Sn	1, 3 <sup>1</sup>	2	3	2	
5	B	2 <sup>0</sup>	1 <sup>0</sup> , 3	2 <sup>0</sup>			28	Ni	1, 3 <sup>3</sup> , 5	2, 4				51	Sb	2, 4 <sup>0</sup>				2
6	C	1, 3	2 <sup>1</sup> , 4	3	2		29	Cu	2 <sup>0</sup> , 4	1, 3				52*	Te	1, 3				
7	N	2, 4	1, 3	2	3		30	Zn	1 <sup>0</sup> , 3	2 <sup>0</sup>	1 <sup>0</sup> , 3			53	I	2				
8*	O	3 <sup>1</sup> , 5	2	3, 5	2	3	31	Ga	2 <sup>1</sup>	3	2			54	Xe	†				
9	F	2, 4	3, 5	2	3		32	Ge	†			2		55	Cs	2 <sup>0</sup>	†			
10	Ne	1 <sup>0</sup> , 3	2, 4				33	As	2, 4 <sup>0</sup>					56	Ba	1 <sup>0</sup> , 3	2			
11	Na	2 <sup>0</sup>	†				34	Se	3 <sup>1</sup> , 5					57	La	2 <sup>2</sup> , 4	1, 3 <sup>3</sup>	2		
12	Mg	1 <sup>0</sup> , 3	2 <sup>0</sup>				35	Br	2					58	Ce				2	
13	Al	2 <sup>1</sup>	1 <sup>0</sup> , 3	2 <sup>0</sup>			36	Kr	†	†				74	W	5 <sup>2</sup> , 7				
14	Si	1, 3 <sup>1</sup>	2 <sup>1</sup> , 4	1 <sup>0</sup> , 3	2 <sup>0</sup>		37	Rb	2 <sup>0</sup>	†				76	Os	†				
15	P	2	3	2, 4	3	2	38	Sr	1 <sup>0</sup> , 3	2 <sup>0</sup>				77	Ir	†				
16	S	3 <sup>1</sup> , 5					39	Yt	2 <sup>1</sup> , 4	1 <sup>0</sup> , 3	2 <sup>2</sup>			78	Pt	1, 3				
17	Cl	2	3, 5	2, 4	3	2, 4	40	Zr	1, 3 <sup>3</sup> , 5	2, 4 <sup>3</sup>		2		79	Au	2 <sup>0</sup>				
18	A	1 <sup>0</sup> , 3					41	Cb	4, 6	5 <sup>2</sup>				80	Hg	1 <sup>0</sup> , 3	2 <sup>0</sup>			
19	K	2	1, 3				42	Mo	5, 7 <sup>0</sup>	4, 6 <sup>0</sup>				81	Tl	2 <sup>1</sup>		2		
20	Ca	1 <sup>0</sup> , 3	2				44	Ru	3, 5 <sup>3</sup>					82	Pb	1, 3 <sup>1</sup>	2 <sup>1</sup>		2	
21	Sc	2 <sup>2</sup> , 4	1, 3 <sup>2</sup>	2 <sup>2</sup>			45	Rh	4 <sup>3</sup> , 6					83	Bi	2, 4 <sup>0</sup>				
22	Ti	1, 3 <sup>3</sup> , 5	2, 4 <sup>3</sup>	3 <sup>3</sup>	2 <sup>2</sup>		46	Pd	1 <sup>0</sup> , 3, 5	2				88	Ra	2 <sup>0</sup>				
23	V	2, 4 <sup>3</sup> , 6	3, 5 <sup>2</sup>	4	3	2														

\* For VI,  $r = 2$  for Os, Cr<sub>24</sub>, Te<sub>52</sub>; for VII,  $r = 2$  for Mn<sub>25</sub>. † See literature reference in next paragraph.

## SOURCES OF DATA

A<sub>18</sub> I (42, 121, 149). Ag<sub>47</sub> I (43, 69, 129), II (7, 106, 157). Al<sub>13</sub> I (43, 69, 129), II and III (127, 151). As<sub>33</sub> I (100, 107, 134). Au<sub>79</sub> I (43, 69, 96, 129, 170). B<sub>5</sub> I (43, 129), II (20, 21, 152), III (17, 152). Ba<sub>56</sub> I (43, 69, 85, 129, 144), II (43, 69, 129). Be<sub>4</sub> I (23, 43, 129), II (23). Bi<sub>83</sub> I (63, 171, 172). Br<sub>35</sub> I (173). C<sub>6</sub> I (43, 49.5, 129), II (14, 17, 20, 123), III (20, 21), IV (17). Ca<sub>20</sub> I (43, 69, 85, 129, 144), II (43, 69, 129, 149.5). Cb<sub>41</sub> I (109), II (114). Cd<sub>48</sub> I (43, 69, 129, 133), II (43, 69, 129, 146). Ce<sub>58</sub> IV (50). Cl<sub>17</sub> I (26, 73, 173); II (16, 72, 128); III, IV, and V (16). Co<sub>27</sub> I (35, 35.5, 120, 138), II (120). Cr<sub>24</sub> I (33, 56), II (84, 115), III (53), V (54), VI (51, 52). Cs<sub>55</sub> I (43, 69, 129), II (159). Cu<sub>29</sub> I (6, 43, 69, 129, 154, 162), II (155). F<sub>9</sub> I (26, 27, 38, 39), II (14, 27), III and IV (14). Fe<sub>26</sub> I (58, 88, 91, 108, 120, 123.5, 176), II (137). Ga<sub>31</sub> I (43, 69, 129, 174), II (131), III (31, 87, 130, 131.5). Ge<sub>32</sub> I (99), IV (31). Gl, see Be. H<sub>1</sub> I (43, 69, 129, 164). He<sub>2</sub> I (41, 43, 69, 75, 93, 129), II (43, 69, 129). Hg<sub>80</sub> I (29, 43, 69, 105, 129, 150), II (31, 43, 69, 129). I<sub>53</sub> I (173). In<sub>49</sub> I (43, 69, 129, 174), II (131), III (31, 86, 87, 130, 131.5).

Ir<sub>77</sub> I (117). K<sub>19</sub> I (43, 69, 129), II (25, 27, 37). Kr<sub>36</sub> I (68, 168), II (77). La<sub>57</sub> I (111, 113), II (61, 112, 113), III (80). Li<sub>3</sub> I (43, 69, 129), II (153, 166, 177). Mg<sub>12</sub> I and II (43, 69, 129). Mn<sub>25</sub> I (1, 32, 43, 69, 97, 129, 138, 180), II (1, 32, 97, 138, 180), III (53), VII (51, 52). Mo<sub>42</sub> I (34, 79, 114, 178), II (114, 178). N<sub>7</sub> I (74, 80), II (14, 36, 44, 48), III (14, 17, 20), IV (20). Na<sub>11</sub> I (43, 69, 129), II (126). Nb, see Cb. Ne<sub>10</sub> I (2, 41, 43, 67, 69, 94, 95, 129), II (28, 78). Ni<sub>28</sub> I (8, 12), II (120, 156). O<sub>8</sub> I (43, 69, 70, 71, 89, 129), II (14, 46, 49, 141), III (14, 47, 122), IV (14, 17, 20), V and VI (22). Os<sub>76</sub> I (117). P<sub>15</sub> I (147, 167), II (15), III (16, 124, 148), IV (20, 148), V (18). Pb<sub>82</sub> I (3, 60, 65, 165, 169, 179), II (57), IV (31). Pd<sub>46</sub> I (5, 10, 103, 104, 117), II (103). Pt<sub>78</sub> I (66, 117). Ra<sub>88</sub> II (43, 69, 129). Rb<sub>37</sub> I (43, 69, 129), II (132). Rh<sub>45</sub> I (114, 117, 160, 163). Ru<sub>44</sub> I (116, 117, 161). S<sub>16</sub> I (30, 43, 69, 70, 73, 129). Sb<sub>51</sub> I (100, 107), V (86). Sc<sub>21</sub> I and II (143), III (51, 52, 158). Se<sub>34</sub> I (43, 69, 70, 101, 129). Si<sub>14</sub> I (43, 45, 76, 129), II (16, 127), III and IV (45). Sn<sub>50</sub> I (4, 62, 64, 165, 181), II (125), III (131), IV (31, 86, 87, 130, 131.5). Sr<sub>38</sub> I (43, 69, 85, 129, 144), II (43, 69, 129). Te<sub>52</sub> I



(101), VI (86).  $Ti_{22}$  I (59, 82, 140), II (136, 139), III (142), IV (51, 52, 142).  $Tl_{31}$  I (43, 69, 129, 133), III (31).  $V_{23}$  I (11, 136, 138, 139), II (110), III (55), IV (54), V (51, 52).  $W_{74}$  I (13, 40, 90).  $Xe_{54}$  I (102).  $Yt_{39}$  I (114, 118, 119), II (114, 119), III (50).  $Zn_{30}$  I (43, 69, 129, 150, 165), II (43, 69, 129, 146), III (92).  $Zr_{40}$  I (81, 114), II (83, 114), IV (50).

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(84) Kiess and Kiess, 532, 33: 255; 25. (85) Kiess and Laporte, 166, 63: 234; 26. (86) Lang, 21, 64: 167; 26. (87) Lang, 197, 13: 341; 27. (88) Lang, 2, 30: 762; 27. (89) Laporte, 96, 23: 135; 24. 26: 1; 24. (90) Laporte, 218, 12: 598; 24. (91) Laporte, 218, 13: 627; 25. (92) Laporte, 197, 12: 496; 26. (93) Laporte and Lang, 2, 30: 378; 27. (94) Lyman, 21, 60: 1; 24. (95) Lyman and Saunders, 2, 25: 886; 25. (96) Lyman and Saunders, 197, 12: 92; 26. (97) McLennan and McLay, 5, 108: 571; 25. 112: 95; 26. (98) McLennan and McLay, 69, 20 III: 89; 26. (99) McLennan and McLay, 69, 20 III: 201; 26. (100) McLennan and McLay, 69, 20 III: 355; 26. (101) McLennan, McLay and McLeod, 3, 4: 486; 27. (102) McLennan and Ruedy, 58, 120: 333; 27. (103) McLennan and Smith, 5, 112: 110; 26. (104) McLennan and Smith, 69, 20 III: 157; 26. (105) McLennan, Smith and Peters, 69, 19 III: 39; 25. (106) Majumdar, 58, 120: 918; 27. (107) Malurkar, 201, 24: 85; 28. (108) Meggers, 21, 60: 60; 24. 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MOLECULAR CONSTANTS DERIVED FROM BAND SPECTRA OF DIATOMIC MOLECULES<sup>1</sup>

RAYMOND T. BIRGE

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## INTRODUCTION

Among spectroscopists it is customary to use in place of the true frequency (in  $\text{sec}^{-1}$ ) the "wave-number," i.e., the number of waves in one cm in a vacuum. As a matter of convenience, a frequency so indicated is often referred to as the "frequency in

<sup>1</sup> Results prior to Dec., 1927.

$\text{cm}^{-1}$  units." Furthermore, on the quantum theory, certain quantities, such as a spectral line, are associated with both definite frequencies and definite amounts of energy, the numerical ratio of the energy to the frequency being the same in all cases. Hence it is often very convenient to express both the energy and the frequency by the same numerical magnitude, and for this the wave-number (in  $\text{cm}^{-1}$ ) is always used. Throughout this report, in the symbolic expressions as well as in the tables, all quantities of the nature of either frequency or energy are expressed in such  $\text{cm}^{-1}$  units. The multiplication of such values by  $c$  ( $=2.99796 \times 10^{10} \text{ cm sec}^{-1}$ ) gives the true frequencies (in  $\text{sec}^{-1}$ ), and by  $hc$  ( $=1.9658 \times 10^{-16} \text{ erg cm}$ ) gives the true energies (in ergs).

From spectral data it is possible to evaluate a set of energy levels for molecules, as well as for atoms. Certain relatively widely spaced levels in molecules seem to correspond to those



known for atoms, and hence are similarly designated and are said to be related to the electronic configuration. A transition from one, often multiple, electronic configuration to another gives rise to an entire system of bands. Each type of transition is correlated with bands of a definite structure. For details, see (40, 41).

In addition to these levels of atomic type, diatomic molecules have two other sets of levels. One corresponds to the mutual vibration, and the other to the mutual rotation, of the two nuclei. To each electronic level corresponds a distinct set of vibrational levels. To a first approximation, the energy corresponding to the level of each member of such a set above the associated electronic level is obtained by giving successive positive integral values to  $n$  in the expression  $n(\omega_0 - \omega_0 x n + \dots)$ ;  $x$  is a positive constant. The frequency ( $\omega$ ) of vibration is obtained by differentiating this with respect to  $n$ ;  $\omega = \omega_0(1 - 2xn + \dots)$ . It varies with  $n$ ; at the lowest level, that at which the amplitude and energy of vibration are vanishingly small,  $n = 0$  and  $\omega = \omega_0$ . A transition from one vibrational level to another gives rise to a single band.

As  $\omega$  is the derivative with respect to  $n$  of the expression for the vibrational energy, the heat of dissociation is  $D = \int_0^{n_0} \omega dn$ , where  $n_0$  is the value of  $n$  for which  $\omega = 0$ . Hence, if the bands can be experimentally followed to  $\omega = 0$ ,  $D$  can be determined from spectroscopic data. Usually this cannot be done, but Birge and Sponer (6) have found that, for the normal state of certain types of molecules, fairly trustworthy values of  $D$  can be obtained by assuming  $\omega = \omega_0(1 - 2xn)$  throughout the range  $n = 0$  to  $n = n_0$ ; then  $D = \omega_0^2/4\omega_0 x$ . It seems that whenever an excited molecule is dissociated, one of the resulting atoms is also excited. If the amount of this excitation is known, it is possible to derive the value ( $D'$ ) of  $D$  for the normal molecule from that ( $D'$ ) of the excited level (see Table 3).

To each vibrational level corresponds a distinct set of rotational levels. These account for the individual lines of a band. To a first approximation, the rotational energy, relative to the vibrational level, is  $Bm^2(1 - m^2u^2 + \dots)$ ;  $m$  is a function of the quantum number  $j$ , but, in general, is not quantized; for zero rotation,  $m = 0$ . Usually  $BI = h/8\pi^2c = 27.70 \times 10^{-40}$  g cm, where  $I$  = moment of inertia of the molecule about an axis through its center of mass and perpendicular to the line joining its nuclei.  $B$  and  $I$  vary with the vibrational energy, and become  $B_0$  and  $I_0$  when that is zero; the corresponding nuclear separation is  $r_0 = \sqrt{I_0/\mu}$ , where  $\mu = m_1m_2/(m_1 + m_2)$ . For multiple levels, like  $^2P$ ,  $B_0I_0$  is not given accurately by  $h/8\pi^2c$ ; see (22, 31).

If  $I'_0 > I''_0$  the band is degraded towards the red. As the vibrational energy increases, the direction of degradation of the bands of a system may reverse.

The relative positions of the energy levels of a molecule may be unambiguously determined from its band spectra, but the interpretation of these levels depends on theory. The new 1926 mechanics (N. M.) of Heisenberg and Schrödinger, and the old (1918-1926) quantum mechanics (O. M.) differ as regards the position of the true electronic level with reference to the observed lowest level of a given set of vibrational and rotational levels. Hence, in general, the derived constants also differ. All data in the following tables refer to O. M.; they may be converted to N. M. by the following relations, in which symbols referring to N. M. are indicated by a bar over them:  $\bar{I}_0 = I_0(1 + u^2/2) \times (1 - \alpha/2B_0)$ ,  $\bar{r}_0 = r_0(1 + u^2/4)(1 - \alpha/4B_0)$ ,  $\bar{\omega}_0 = \omega_0(1 + x)(1 - \alpha/4\omega_0)$ ;  $\bar{\omega}_0 x = \omega_0 x$ ,  $\bar{v}_0 = v_0 + s'' - s'$  where  $s = 0.5\omega_0(1 + 0.5x)$ .

These transformation equations are based on the  $Bj(j+1)$  form of the rotational energy, in the N. M. Further refinements seem to indicate that the true form is  $B(j + \frac{1}{2})^2$ , and in that case the factors containing  $u^2/2$ ,  $u^2/4$ , and  $\alpha/4\omega_0$  should be omitted.

The value of  $\alpha$  is known for only a few systems (for CN, NO, and AlO,  $\alpha/B_0 = 0.01$ ; for H<sub>2</sub>,  $\alpha/B_0 = 0.04$ ), and is not given in the following tables; it is positive, and  $\alpha/2B_0$  is of the order of 0.01;  $x$  is of the same order; neither is negligible;  $u^2/2$  and  $\alpha/4\omega_0$  are of the order of  $10^{-4}$  to  $10^{-6}$  and are negligible.

A full account of the quantum analysis of molecular spectra (O. M.) is given in (1); previous tables of constants derived from band spectra (1, 36, 37, 38); complete bibliography (36, 38, 38.1). The O. M. is used consistently in (36) and, excepting BO bands, in (1), and is normally used in (37, 38), but occasionally in these, N. M. values given by the original investigators are inadvertently copied.

## SYMBOLS AND CONSTANTS

(The values used for  $h$ ,  $c$ , and especially  $R$  differ from those given in Vol. I); see Introduction regarding units.

- $B$  A quantity, of the nature of (length)<sup>-1</sup>, related to the moment of inertia of the molecule in such a way that the rotational energy, relative to the vibrational level, is given to the first approximation by  $Bm^2(1 - m^2u^2 + \dots)$ . It varies with the vibrational energy;  $B = B_0 - \alpha n$ . Usually  $BI = h/8\pi^2c = 27.70 \times 10^{-40}$  g cm.
- $B_0$  Value of  $B$  when vibrational and rotational energies are each zero. For multiple levels like  $^2P$ ,  $B_0I_0 \neq h/8\pi^2c$  (22, 31).
- $c$  Velocity of light in vacuo;  $c = 2.99796 \times 10^{10}$  cm/sec.
- $D$  Heat of dissociation of the molecule.
- $D', D''$  Value of  $D$  for upper state, for lower (in Table 3, normal) state, of molecule.
- $E$  Wave-number  $\approx$  elevation of electronic energy above normal level. (In line spectra, the corresponding quantity is so defined as to indicate the depression of a given level below ionization.)
- $e$  Electronic charge;  $e = 4.774 \times 10^{-10}$  cgs electrostatic unit.
- $e/hc$  The reciprocal of the potential difference that corresponds to the transition that gives rise to radiation of wave-length  $\lambda$  is  $e\lambda/hc$ ;  $e/hc = 2.428 \times 10^8$  cgs = 8100 volt<sup>-1</sup> cm<sup>-1</sup>.
- $h$  Planck's constant of action;  $h = 6.557 \times 10^{-27}$  erg sec.
- $I$  Moment of inertia of the molecule about the line through its center of mass and perpendicular to the line joining its two nuclei.
- $I_0$  Value of  $I$  when vibrational and rotational energies are zero.
- $I'_0, I''_0$  Value of  $I_0$  for upper state, for lower state, of molecule.
- $m$  A parameter in the approximate expression,  $Bm^2(1 - m^2u^2 + \dots)$ , giving the rotational energy relative to vibrational level. It is a function of  $j$ , the quantum number correlated with the resultant angular momentum of the molecule, but, in general, is not quantized.
- $m_0$  Mass of atom of unit atomic weight;  $m_0 = m_H/1.0077 = 1.650 \times 10^{-24}$  g.
- $m_H$  Mass of atom of hydrogen;  $m_H = 1.663 \times 10^{-24}$  g.
- $m_1, m_2$  Atomic weights of the two atoms composing the molecule.
- $n$  A positive and integral parameter in the equations expressing the vibrational frequency,  $\omega = \omega_0(1 - 2xn + \dots)$ , and the vibrational energy,  $n(\omega_0 - \omega_0 x n + \dots)$ , relative to the electronic level.
- N. M. New mechanics (1926-) of Heisenberg and Schrödinger.
- O. M. Old quantum mechanics (1918-1926).
- $R$  Rydberg's wave-number =  $109\,678.3$  cm<sup>-1</sup>.

Continued on p. 417



TABLE 1.—CONSTANTS OF DIATOMIC MOLECULES

These data are derived on the O. M. basis from the quantum analysis of band spectra; many have been recomputed, either directly from the observations or from the value of  $B_0$ ; the former are indicated by an  $r$  and the latter by a  $b$  placed after the Lit. number. All assume that both vibrational and rotational energy are vanishingly small. Each line of the table refers to one system of bands,  $\nu$ , is the spacing of the two electronic levels involved. (O), (H), indicates that  $\nu$  is derived from origin, from head, of the 0-0 band. The (H) values may be in error by 5 to 20  $\text{cm}^{-1}$ , being too great for the R, and too small for the V, bands. After the value of  $\omega_0 x$  is given the sign, if known, of the next higher term in the expression,  $n(\omega_0 - \omega_0 x + \dots)$ , for the vibrational energy. When only the first two vibrational levels are known,  $\omega_0 - \omega_0 x$ , is their resulting separation, is given in ( ). It is known (25) that  $I_0$ , and hence  $r_0$ , is essentially the same for each of the  $^3P$  sublevels involved in the NO  $\beta$ -bands, and it is probable [cf. (22, 31)] that the same is true in other cases, the true value of  $I_0$  in each case being essentially the mean of the two values here given. Symbols, p, 410. See p. 409. Unit of  $\nu$ ,  $\omega_0$ , and  $\omega_0 x = 1 \text{ cm}^{-1} \approx 2.99796 \times 10^{10} \text{ vibration sec}^{-1}$ ; of  $I_0 = 10^{-40} \text{ g cm}^2 = 10^{-14} \text{ g Å}^2$ ; of  $r_0 = 10^{-8} \text{ cm} = 1 \text{ Å}$ .

Name of band	Carrier	$\nu$	Upper		Lower		Lit.	Upper, $I'_0$	Lower, $I''_0$	Upper, $r'_0$	Lower, $r''_0$	Type	Lit.
			$\omega'_0$	$\omega'_0 x'$	$\omega''_0$	$\omega''_0 x''$							
Silver bromide.....	AgBr	R 31 337(H)			247.2	0.81	(13)r	4.57	4.38	1.665	1.630	$^1S - ^1S$	(1)
Silver.....	AgH	R 29 898(O)	(1490)		(1690)		(1)						
Silver iodide.....	AgI	R 31 148(H)			205.8	0.56	(13)r						
Aluminum hydride.....	AlH	R 23 477.0(O)	(1082)		(1625.1)		(1)	4.58	4.41	1.690	1.658	$^1S - ^1P$	(1)
Aluminum.....	AlO	R 20 635.3(O)	864.4	3.75	970	7.0	(1)	46.02	43.38	1.667	1.618	$^2S - ^2S$	(1)*
Gold chloride A.....	AuCl	R 19 078.5(H)	311.3	0.70	381.5	1.30	(11)						
Gold chloride B.....	AuCl	R 19 396.8(H)	314.85	1.45	381.5	1.30	(11)						
Gold.....	AuH	R 27 342.1(O)	1630	79	2249.4	34.0	(1)	4.74	3.93	1.69	1.54	$^1S - ^1S$	(1)
Gold.....	AuH	R 38 230.0(O)	(1548)		2249.4	34.0	(1)					$^1S - ^1S$	
BO $\alpha$ -group.....	B <sup>10</sup> O	R { 23 647.5(O) 23 521.3(O)	1248.5	10.6	1873.7	11.71	(1)†	{ 19.62 20.03	{ 15.68 15.68	{ 1.3506 1.3647	{ 1.2074 1.2074	{ $^2S - ^2P_1$ $^2S - ^2P_2$	{ (24)† (24)†
BO $\alpha$ -group.....	B <sup>10</sup> O	R { 23 639.3(O) 23 513.1(O)	1286.3	11.7	1928.1	12.39	(1)†	{ 18.53 14.81	{ 14.81 14.81	{ 1.3510 .....	{ 1.2078 1.2078	{ $^2S - ^2P_1$ $^2S - ^2P_2$	{ (24)† (24)†
BO $\beta$ -group.....	B <sup>10</sup> O	R { 42 865.2(O) 42 856.0(O)	1270.2	10.07	1873.7	11.71	(1)†	18.53	15.68	1.3126	1.2074	$^2S - ^2S$	(1)§
BO $\beta$ -group.....	B <sup>10</sup> O	R { 42 856.0(O) 19 343.9(O)	1306.2	10.53	1928.1	12.39	(1)†	17.48	14.81	1.3121	1.2078	$^2S - ^2S$	(1)§
BO "combination".....	B <sup>10</sup> O	V { 19 217.7(O) 19 342.9(O)	1270.2	10.07	1248.5	10.6	(1)†	{ 20.03 19.62	{ 15.68 15.68	{ 1.3126 1.3126	{ 1.3647 1.3506	{ $^2P_2 - ^2S$ $^2P_1 - ^2S$	{ (1)§ (1)§
BO "combination".....	B <sup>10</sup> O	V { 19 216.7(O) 19 342.9(O)	1306.2	10.53	1286.3	11.7	(1)†	17.48	{ 18.53 18.53	1.3121	{ 1.3510 1.3510	{ $^2P_2 - ^2S$ $^2P_1 - ^2S$	{ (1)§ (1)§
Barium fluoride.....	BaF	R 19 997.3(H)	452.9	1.75	465.0	1.85	(37, 38)					$^2S - ^2P$	
Barium oxide.....	BaO	R 14 664(H)	510	2.7	664	1.5	(37, 38)						
Beryllium fluoride.....	BeF	R { 33 215(H) 33 180(H)	1157	8	1250	12	(1)						
Beryllium oxide.....	BeO(?)	R 21 231.6(H)	1354	8.9	1465	12.7	(1)					$^1S - ^1S$	
Bismuth oxide.....	BiO	R 22 196(H)	410	3	530	7	(37, 38)						
Bromine.....	Br <sub>2</sub>	R 16 463(H)	151	1.82-	326.6	1.72	(33)r					$^1S - ^1S(?)$	
Swan.....	C <sub>2</sub> (?)	V 19 379.2(O)¶	1773.42	19.35	1629.88	11.67	(23)	15.84	17.03	1.265	1.311	$^2P - ^2P$	(1)

\* Using 26.96 for atomic weight of Al.

† In terms of O. M., the origins and nuclear separations are not the same for each isotope. For values in N. M., see (1).

‡ The two isotopes have essentially the same  $r_0$ , but different  $I_0$ ;  $^2P$  doublet is inverted.

§ Data for  $I'_0$  and  $r'_0$  are taken from  $\alpha$ -group, final state; for  $I''_0$  and  $r''_0$  from initial state plus  $C_0$  (24.5) of  $\beta$ -group.

|| Data for  $I'_0$  and  $r'_0$  are taken from  $\alpha$ -group, initial state; for  $I''_0$  and  $r''_0$  as in note §. The  $^2P$  doublet is inverted (24).

¶ From (48).



TABLE 1.—(Continued)

Name of band	Carrier	Shaded	$\nu_0$	Upper		Lower		Lit.	Upper, $I'_0$	Lower, $I''_0$	Upper, $r'_0$	Lower, $r''_0$	Type	Lit.
				$\omega'_0$	$\omega'_0 x'$	$\omega''_0$	$\omega''_0 x''$							
High pressure carbon	C <sub>2</sub> (?)	V	22 972.7(H)			1537.3	11.88	(1)						
Triplet carbon	C + H(?)	R	{ 15 540(O) 15 623(O) }	1105	9.8	(1714)		(1)						
C + H ( $\lambda$ 4300)	CH	V	23 163.3(O)	(2851)		(2797) and (2815)		(1)	1.90	1.95	1.11	1.13	$^1P - ^2D$	(1)
C + H ( $\lambda$ 3900)	CH	R	25 715(O)					(1)	2.21	1.95	1.20	1.13	$^1P - ^2S$	(1)
Violet cyanogen	CN	V	25 797.8(O)	2143.9	20.25 -	2055.64	13.75	(1)	14.140	14.647	1.151	1.172	$^2S - ^2S$	(1)
Red cyanogen	CN	R	{ 14 430(O?) 14 374(O?) }	1728.5	13.5	2055.64	13.75	(1)					$\begin{cases} ^2S - ^2P_1 \\ ^2S - ^2P_2 \end{cases}$	§
Fourth positive group of carbon	CO	R	64 765(H)	1499.0	17.24	2154.7	12.70	(1, 19)					$^1S - ^1P$	(1)
Ångström CO	CO	V	22 164(O)	2132	50	1499.0	17.24	(1, 19)	14.26	17.31	1.122	1.236	$^1P - ^1S$	(1)
Third positive group of carbon	CO	V	35 300*(H)	(2214) (?)		1724.78	14.47	(1)					$^1P - ^1S$	(1)
3A bands of CO	CO	V	43 600†(H)	(2133)		1724.78	14.47	(2, 10)					$^1S - ^1P$	
Cameron CO	CO	R	48 500†(H)	1724.8	14.5	2154.7	12.70	(1, 19); cf. (2)						
$\alpha' - X$ CO	CO	R	58 927(O)	1155	9	2154.7	12.70	(19)						
$F - X$ CO	CO	R(?)	99 730(O)	1914	198	2154.7	12.70							
Infra-red CO	CO	R	Zero	2148	9.7	2148	9.7	(1)	14.9	14.9	1.15	1.15	$^1S$	(1)
First negative group of carbon	CO+	R	45 637.7(O)	1697.8	24.33	2197.03	15.17	(1)	15.4	14.05	1.17	1.11	$^2S - ^2S$	(1)
Comet-tail	CO+	R	{ 20 471.6(O) 20 346.1(O) }	1550.46	14.07 +	2198.6	15.00	(1)	17.7(?)	14.05	1.25(?)	1.11	$\begin{cases} ^2S - ^2P_1 \\ ^2S - ^2P_2 \end{cases}$	(1)§
"Combination"	CO+	V	{ 25 285(O) 25 158(O) }	1697.8	24.33	1550.46	14.07 +	(1)					$\begin{cases} ^2P_2 - ^2S \\ ^2P_1 - ^2S \end{cases}$	§
Carbon sulfide	CS	R	38 796.3	1062.2	10.05	1276.5	6.00	(25)					$^1S - ^1P$	
Calcium fluoride	CaF	V	{ 16 559(H) 16 485(H) }	588.1	2.93	582.4	2.75	(37, 38)					$^2S - ^2P$	
Calcium hydride A	CaH	R¶	{ 14 472.20(O) 14 392.30(O) }					(20)	6.77	6.56	2.04	2.01	$\begin{cases} ^2S - ^2P_2 \\ ^2S - ^2P_1 \end{cases}$	(20)
Calcium hydride B	CaH	V	15 753.84(O)					(20)	6.29	6.56	1.97	2.01	$^2S - ^2S$	(20)
Calcium hydride C	CaH	V	28 353.04(O)					(20)	5.84	6.56	1.86	2.01	$^2S - ^2S$	(20)
Calcium oxide	CaO	R	23 057(H)	740	3.3	848	4	(37)						
Cadmium hydride	CdH	V	{ 22 278(O) 23 279(O) }			1374		(1)	{ 4.647 4.594 }	5.201	1.679	1.776	$^2S - ^2P_1$	(1)
Chlorine absorption	Cl <sub>2</sub>	R	19 563(H)	185.5	4.83 -	570	4.6	(23)r					$^2S - ^2P_2$	
Chromium oxide	CrO	R	{ 16 520(H) 16 500(H) }	742	9.5	891	6	(37, 38)					$^1S - ^1S?$	

\*  $\nu_0$  at least 5-fold, varying from 35 288 to 35 390.†  $\nu_0$  at least 5-fold, varying from 43 558 to 43 655.‡  $\nu_0$  at least 5-fold, varying from 48 534 to 48 438;  $\omega_0$  and  $\omega_0 x'$  are from 3rd and 4th positive groups.§ The  $^2P$  doublet is assumed inverted because for BO it is found (24) to be inverted.|| Hopfield and Birge (19) absorption system;  $\omega''_0$  is from 4th group. There are other new absorption systems from X-level to levels b and B (Table 2), to new levels C, E, G, and probably several higher ones; cf. Table 2.¶ For small values of  $j$ ,  $I'_0$  being  $> I''_0$ ; for higher values,  $V$ ,  $I'_0$  being  $< I''_0$ . The band sequences may degrade to V; cf. CuF.



TABLE 1.—(Continued)

Name of band	Carrier	$\nu$	Upper		Lower		Lit.	Upper, $I'_0$	Lower, $I''_0$	Upper, $r'_0$	Lower, $r''_0$	Type	Lit.
			$\nu_0$	$\omega'_0$	$\nu_0$	$\omega''_0$							
Copper bromide A.....	Cu <sup>63</sup> Br <sup>79</sup>	R	295.12	1.008	312.70	0.800	(43)						
Copper bromide A.....	Cu <sup>63</sup> Br <sup>61</sup>	R	293.50	0.997	310.98	0.791	(43)*						
Copper bromide A.....	Cu <sup>63</sup> Br <sup>79</sup>	R	292.59	0.991	310.01	0.786	(43)*						
Copper bromide A.....	Cu <sup>63</sup> Br <sup>61</sup>	R	290.95	0.980	308.28	0.778	(43)*						
Copper bromide B.....	Cu <sup>63</sup> Br <sup>79</sup>	R	282.90	1.323	313.16	0.908	(43)						
Copper bromide B.....	Cu <sup>63</sup> Br <sup>61</sup>	R	281.34	1.309	310.44	0.898	(43)*						
Copper bromide B.....	Cu <sup>63</sup> Br <sup>79</sup>	R	280.47	1.300	310.42	0.892	(43)*						
Copper bromide B.....	Cu <sup>63</sup> Br <sup>61</sup>	R	278.89	1.286	308.73	0.883	(43)*						
Copper bromide C.....	Cu <sup>63</sup> Br <sup>79</sup>	R	284.78	1.423	313.83	0.888	(43)						
Copper bromide C.....	Cu <sup>63</sup> Br <sup>61</sup>	R	283.16	1.407	312.10	0.878	(43)*						
Copper bromide C.....	Cu <sup>63</sup> Br <sup>79</sup>	R	282.25	1.398	311.13	0.873	(43)*						
Copper bromide C.....	Cu <sup>63</sup> Br <sup>61</sup>	R	280.61	1.383	309.39	0.863	(43)*						
Copper chloride A.....	Cu <sup>63</sup> Cl <sup>35</sup>	R	407.9	1.90	415.7	1.90	(43)						
Copper chloride B.....	Cu <sup>63</sup> Cl <sup>35</sup>	R	399.04	1.669	415.22	1.682	(43)						
Copper chloride B.....	Cu <sup>63</sup> Cl <sup>37</sup>	R	396.84	1.649	412.93	1.664	(43)*						
Copper chloride B.....	Cu <sup>63</sup> Cl <sup>37</sup>	R	392.05	1.610	407.94	1.624	(43)*						
Copper chloride B.....	Cu <sup>63</sup> Cl <sup>37</sup>	R	389.81	1.591	405.62	1.605	(43)*						
Copper chloride C.....	Cu <sup>63</sup> Cl <sup>35</sup>	R	397.45	1.654	415.53	1.648	(43)						
Copper chloride C.....	Cu <sup>63</sup> Cl <sup>37</sup>	R	395.26	1.636	413.24	1.630	(43)*						
Copper chloride C.....	Cu <sup>63</sup> Cl <sup>37</sup>	R	390.48	1.596	408.25	1.591	(43)*						
Copper chloride C.....	Cu <sup>63</sup> Cl <sup>37</sup>	R	388.26	1.578	405.92	1.573	(43)*						
Copper chloride D.....	Cu <sup>63</sup> Cl <sup>35</sup>	R	393.16	1.839	415.57	1.679	(43)						
Copper chloride D.....	Cu <sup>63</sup> Cl <sup>35</sup>	R	390.94	1.819	415.28	1.656	(43)*						
Copper chloride D.....	Cu <sup>63</sup> Cl <sup>37</sup>	R	386.27	1.775	408.29	1.616	(43)*						
Copper chloride D.....	Cu <sup>63</sup> Cl <sup>37</sup>	R	384.07	1.755	405.96	1.597	(43)*						
Copper chloride E.....	Cu <sup>63</sup> Cl <sup>35</sup>	R	404.07	1.818	414.90	1.278	(43)						
Copper chloride E.....	Cu <sup>63</sup> Cl <sup>35</sup>	R	401.84	1.798	412.61	1.264	(43)*						
Copper chloride E.....	Cu <sup>63</sup> Cl <sup>37</sup>	R	396.99	1.755	407.63	1.234	(43)*						
Copper chloride E.....	Cu <sup>63</sup> Cl <sup>37</sup>	R	394.73	1.735	405.30	1.220	(43)*						
Copper fluoride A.....	Cu <sup>63</sup> F	R†	638.33	3.488	612.84	3.625	(43)						
Copper fluoride B.....	Cu <sup>63</sup> F	R†	647.62	3.725	612.84	3.625	(43)						
Copper fluoride B.....	Cu <sup>63</sup> F	R†	645.31	3.698	610.65	3.599	(43)*						
Copper fluoride C.....	Cu <sup>63</sup> F	R†	640.88	4.188	618.70	3.950	(43)						
Copper fluoride C.....	Cu <sup>63</sup> F	R†	638.59	4.158	616.49	3.922	(43)*						
Copper hydride.....	CuH	R	1655.70	44.63	1903.68	37.36	(1)	4.097	3.544	1.582	1.471	1S - 1S	(1)
Copper iodide A.....	Cu <sup>63</sup> I	R	211.05	2.215	284.93	0.719	(43)						
Copper iodide B.....	Cu <sup>63</sup> I	R	241.8	1.88	285.4	1.0	(1)						
Copper iodide C.....	Cu <sup>63</sup> I	R	229.17	0.528	283.90	0.728	(43)						
Copper iodide D.....	Cu <sup>63</sup> I	R	211.86	0.917	263.83	0.704	(43)						
Copper iodide E.....	Cu <sup>63</sup> I	R	228.28	0.954	263.81	0.671	(1)						
Fluorine.....	F <sub>2</sub>	R	1104.9(?)	2.9(?)	1071.5(?)	9.9	(17)†		29†		1.4	1S - 1S(?)	(17)

\* Calculated from observed bands of main (first listed) isotope of the system. (E.g., Cu<sup>63</sup>Br<sup>79</sup> is the main isotope of CuBr for each of the three systems, A, B, and C.) All systems of each molecule have the same lower level.

† CuF is the only known case for which band sequences degrade to V while bands degrade to R; cf. CaH, A bands.

‡ Analysis by Gale and Monk (16, 17) is very uncertain. An intercomparison of the halogens gives as more probable predicted values:  $\nu_0 = 23\ 000$  to  $25\ 000$ ,  $\omega'_0 = 320$ ,  $\omega'_0 x' = 15$  to  $20$ ,  $\omega''_0 = 1170$ ,  $\omega''_0 x'' = 10$ . Mecke (37) rightly gives  $I''_0 = 29$ , which is double their value, and checks with values for other halogens.



TABLE 1.—(Continued)

Name of band	Carrier	Polarization	$\nu_s$	Upper			Lit.	Upper, $I_0'$	Lower, $I_0'$	Upper, $r_0'$	Lower, $r_0'$	Type	Lit.
				$\omega_0'$	$\omega_0''$	$\omega_0'''$							
Hydrogen A-B ultra-violet.....	H <sub>2</sub>	R	90 083(O)	1325	4282	113.5	(3)	1.99	0.480	1.55	0.76	1 <sup>1</sup> S - 2 <sup>1</sup> S	(3)
Hydrogen A-C ultra-violet.....	H <sub>2</sub>	R	99 086(O)	2380	4282	113.5	(3)	0.942	0.480	1.06	0.76	1 <sup>1</sup> S - (?)	(3)
Hydrogen A.....	H <sub>2</sub>	V	21 573.8(O)	2373.8	1325	15.9	(3)	1.99	1.99		1.55	2 <sup>1</sup> S - 3 <sup>1</sup> P	(3)
Hydrogen B.....	H <sub>2</sub>	V	27 133.9(O)	2325.6(?)	1325	15.9	(3)	1.99	1.99		1.55	2 <sup>1</sup> S - 4 <sup>1</sup> P	(3)
Hydrogen 2 <sup>1</sup> P - 3 <sup>1</sup> S.....	H <sub>2</sub>	R	16 692.0(O)	2390	73		(3)	0.78	0.78		0.97	2 <sup>1</sup> P - 3 <sup>1</sup> S	(3)
Hydrogen $\alpha$ (Fulcher).....	H <sub>2</sub>	R	16 611.43(O)	2306.94	2593.82	68.41	(3)	1.072	0.965	1.136	1.08	2 <sup>1</sup> S - 3 <sup>1</sup> P	(3)
Hydrogen $\beta$ .....	H <sub>2</sub>	R	22 263.24(O)	2276.45	2593.82	68.41	(3)	1.089	0.965	1.145	1.08	2 <sup>1</sup> S - 4 <sup>1</sup> P	(3)
Hydrogen $\gamma$ .....	H <sub>2</sub>	R	24 839.05(O)	2251	2593.82	68.41	(3)	1.135	0.965	1.168	1.08	2 <sup>1</sup> S - 5 <sup>1</sup> P	(3)
Hydrogen $\delta$ .....	H <sub>2</sub>	R	26 224.21(O)	2229(?)	2593.82	68.41	(3)	1.130	0.965	1.166	1.08	2 <sup>1</sup> S - 6 <sup>1</sup> P	(3)
Hydrogen $\epsilon$ .....	H <sub>2</sub>	R	27 054.45(O)		2593.82	68.41	(3)		0.965		1.08	2 <sup>1</sup> S - 7 <sup>1</sup> P	(3)
Hydrogen $\zeta$ .....	H <sub>2</sub>	R	27 592.52(O)		2593.82	68.41	(3)		0.965		1.08	2 <sup>1</sup> S - 8 <sup>1</sup> P	(3)
HBr near infra-red.....	HBr	R	Zero	2603	44		(1, 7)*	3.303	3.303	1.418	1.418	1 <sup>1</sup> S	(1)
HBr far infra-red.....	HBr		Zero	Zero				3.3180	3.3180	1.4213	1.4213	1 <sup>1</sup> S	(3)b
HCl near infra-red.....	HCl	R	Zero	2940.8	53.6		(1, 30)†	2.645	2.645	1.279	1.279	1 <sup>1</sup> S	(1)
HCl far infra-red.....	HCl		Zero	Zero				2.6593	2.6593	1.2823	1.2823	1 <sup>1</sup> S	(3)b
HF near infra-red.....	HF	R	Zero	3987	50		(1)‡	1.35	1.35	0.924	0.924	1 <sup>1</sup> S	(1)
HF far infra-red.....	HF		Zero	Zero				1.3465	1.3465	0.9233	0.9233	1 <sup>1</sup> S	(3)b
HI far infra-red.....	HI		Zero	Zero				4.3146	4.3146	1.6170	1.6170	1 <sup>1</sup> S	(3)b
He <sub>2</sub> main P series ( $\lambda$ 4648).....	He <sub>2</sub>	R	21 507.3(O)	(1643.5)	(1731.8)		(52)	{ 3.861 3.900 }	3.650	{ 1.082 1.087 }	1.052	2 <sup>1</sup> S <sub>m</sub> - 3 <sup>1</sup> P <sub>m</sub>	(40)b§
He <sub>2</sub> main P series ( $\lambda$ 3676).....	He <sub>2</sub>	R	27 193.0(O)	(1627.8)	(1731.8)		(52)	{ 3.879 3.976 }	3.650	{ 1.084 1.098 }	1.052	2 <sup>1</sup> S <sub>m</sub> - 4 <sup>1</sup> P <sub>m</sub>	(40)b§
He <sub>2</sub> main P series ( $\lambda$ 3556).....	He <sub>2</sub>	R	29 785.5(O)		(1731.8)		(52)	{ 3.865 3.989 }	3.650	{ 1.085 1.099 }	1.052	2 <sup>1</sup> S <sub>m</sub> - 5 <sup>1</sup> P <sub>m</sub>	(40)b§
He <sub>2</sub> main P series ( $\lambda$ 3206).....	He <sub>2</sub>	R	31 180.0(O)	(1623.8)	(1731.8)		(52)	{ 3.892 4.121 }	3.650	{ 1.086 1.117 }	1.052	2 <sup>1</sup> S <sub>m</sub> - 6 <sup>1</sup> P <sub>m</sub>	(40)b§
He <sub>2</sub> main P series ( $\lambda$ 3071).....	He <sub>2</sub>	R	32 556.8(O)		(1731.8)		(52)¶	{ 3.895 4.168 }	3.650	{ 1.086 1.124 }	1.052	2 <sup>1</sup> S <sub>m</sub> - 7 <sup>1</sup> P <sub>m</sub>	(40)b§
He <sub>2</sub> main S series ( $\lambda$ 6399).....	He <sub>2</sub>	R	15 623.9(O)				(52)¶¶	3.84	3.784	1.079	1.071	2 <sup>1</sup> P <sub>m</sub> - 3 <sup>1</sup> S <sub>m</sub>	(40)b
He <sub>2</sub> main S series ( $\lambda$ 4546).....	He <sub>2</sub>	R	21 992.8(O)				(52)¶¶	3.88	3.784	1.084	1.071	2 <sup>1</sup> P <sub>m</sub> - 4 <sup>1</sup> S <sub>m</sub>	(40)b
He <sub>2</sub> main S series ( $\lambda$ 4030).....	He <sub>2</sub>	R	24 804(O)				(52)		3.784		1.071	2 <sup>1</sup> P <sub>m</sub> - 5 <sup>1</sup> S <sub>m</sub>	(40)b
He <sub>2</sub> main D series ( $\lambda$ 5733).....	He <sub>2</sub>	V	17 436.6(O)				(52)	3.866	3.784	1.054	1.071	2 <sup>1</sup> P <sub>m</sub> - 3 <sup>1</sup> D <sub>m</sub>	(40)b
He <sub>2</sub> secondary P series ( $\lambda$ 5133).....	He <sub>2</sub>	R	19 476.9(O)		(1790.1)		(52)	{ 3.86 3.89 }	3.62	{ 1.08 1.09 }	1.047	2 <sup>1</sup> S <sub>s</sub> - 3 <sup>1</sup> P <sub>s</sub>	(40)b§
He <sub>2</sub> secondary P series ( $\lambda$ 4002).....	He <sub>2</sub>	R	24 978.6(O)		(1790.1)		(52)	3.90	3.62	1.09	1.047	2 <sup>1</sup> S <sub>s</sub> - 4 <sup>1</sup> P <sub>s</sub>	(40)b§
He <sub>2</sub> secondary P series ( $\lambda$ 3634).....	He <sub>2</sub>	R	27 509.9(O)		(1790.1)		(52)	3.97	3.62	1.10	1.047	2 <sup>1</sup> S <sub>s</sub> - 4 <sup>1</sup> P <sub>s</sub>	(40)b§
He <sub>2</sub> secondary P series ( $\lambda$ 3462).....	He <sub>2</sub>	R	28 875.0(O)		(1790.1)		(52)	3.86	3.62	1.08	1.047	2 <sup>1</sup> S <sub>s</sub> - 5 <sup>1</sup> P <sub>s</sub>	(40)b§
He <sub>2</sub> combination ( $\lambda$ 600.13).....	He <sub>2</sub>	R	166 631(H)		(1790.1)		(52)	4.11	3.62	1.11	1.047	2 <sup>1</sup> S <sub>s</sub> - 6 <sup>1</sup> P <sub>s</sub>	(40)b§
Mercury hydride.....	HgH	V	{ 24 933.9(O) 28 617.1(O) }	(1940)	{ 1308 1308 }	104 - 104 -	(1)††	{ 4.220 4.181 }	5.143 5.143	1.597 1.589	1.763 1.763	{ 1 <sup>1</sup> S - 2 <sup>1</sup> P <sub>1</sub> 2 <sup>1</sup> S - 2 <sup>1</sup> P <sub>2</sub> }	(47)**

\* From 1st harmonic at  $\lambda = 1.988 \mu$  (7).† Second overtone at  $\lambda = 1.190 \mu$  (45) indicates third term of  $\omega_s$  is +; values of  $\omega_s$  and  $\omega_{sz}$  from (39).‡ From 1st harmonic at  $\lambda = 1.27 \mu$  (45).§ Double values of  $I_0$  are due to sigma-type doubling in P-levels.¶ Two more <sup>1</sup>P series bands at  $\nu_s = 32 926.4$  and  $33 189.0 \text{ cm}^{-1}$ ; other constants unknown.

¶¶ The 1-1 band also observed.

\*\* The assignment of this band is extremely doubtful.

†† Mecke's (37) values ( $\omega_s = 2036.1$ ,  $\omega_{sz} = 98.3$ ) are based on older and incorrect assumption that  $28 617.1 \text{ cm}^{-1}$  band is 0-0 band of short  $\lambda$ -system.



TABLE 1.—(Continued)

Name of band	Carrier	$\nu$	Upper		Lower		Lit.	Upper, $I'_0$	Lower, $I''_0$	Upper, $r'_0$	Lower, $r''_0$	Type	Lit.
			$\omega'_0$	$\omega'_x$	$\omega''_0$	$\omega''_x$							
Iodine.....	I <sub>2</sub>	15 598.3(H)	127.2	0.834—	213.67	0.592—	(1) <sup>r</sup>	951.6	742.6	3.015	2.668	<sup>1</sup> S— <sup>1</sup> S(?)	(1)
Iodine monochloride.....	ICl	15 390(H)	176.3	3.025—	(388)		(17.8) <sup>r</sup>						
Near red potassium.....	K <sub>2</sub>	15 368.6(H)	74.72	0.30	91.96	0.29	(15) <sup>r</sup>	139.5	87.4	2.079	1.647	<sup>1</sup> S— <sup>1</sup> P	(15)
Magnesium fluoride.....	MgF	27 825.5(H)	713.5	3.80	684.1	3.70	(37, 38)						
Magnesium hydride.....	MgH	19 271(O)	1568.7	34.75	1462.2	31.25	(39) <sup>†</sup>	4.62	4.86	1.70	1.74	<sup>1</sup> S— <sup>2</sup> P	(31)
Manganese oxide.....	MnO	17 906(H)	758.9	10.2	836.7	5.06	(37, 38)						
N <sub>2</sub> 1st positive group.....	N <sub>2</sub>	9 518.59(H)	1718.40	14.437—	1446.46	13.929—	(1) <sup>r</sup>					<sup>1</sup> S— <sup>2</sup> P	
N <sub>2</sub> 2nd positive group.....	N <sub>2</sub>	29 653.1(H)	2018.66	26.047—	1718.40	14.437—	(1)	15.24	16.98	1.149	1.212	<sup>2</sup> P— <sup>2</sup> P	(1)
N <sub>2</sub> 4th positive group.....	N <sub>2</sub>	44 218(H)	1679.2	13.845	1718.40	14.437—	(1)					<sup>2</sup> P—(?)	
N <sub>2</sub> ultra-violet.....	N <sub>2</sub>	68.957.0(H)			2345.16	14.445	(1, 6)					<sup>1</sup> S— <sup>1</sup> P	
N <sub>2</sub> new ultra-violet.....	N <sub>2</sub>	103 671.7(H)					(5)					<sup>1</sup> S—(?)	
N <sub>2</sub> new ultra-violet.....	N <sub>2</sub>	104 415.6(H)					(5)					<sup>1</sup> S—(?)	
First negative group of nitrogen.....	N <sub>1</sub> <sup>+</sup>	25 565.9(O)	2392.3	22.8—	2187.4	16.3	(1)	13.35	14.41	1.075	1.117	<sup>1</sup> S— <sup>2</sup> S	(1)
Nitrogen hydride β.....	NH	29 750(O)					(21)		1.81		1.08	<sup>1</sup> S— <sup>2</sup> P	(21)
Third positive, or γ, of nitrogen.....	NO <sup>‡</sup>	44 072(O)	2352	13—	1888.31	13.88	(1)	14.05	16.35	1.068	1.152	<sup>2</sup> P <sub>1</sub> — <sup>2</sup> S	(19)¶
β of nitrogen.....	NO <sup>‡</sup>	44 193(O)	1029.43	7.460+	1892.12	14.424+						<sup>2</sup> P <sub>1</sub> — <sup>2</sup> S	
β of nitrogen.....	NO <sup>‡</sup>	45 486.12(O)	1030.88	7.455+	1891.98	14.454+	(25)	24.80	16.29	1.418	1.150	<sup>2</sup> P <sub>1</sub> — <sup>2</sup> P <sub>1</sub>	(25)
β nitric oxide.....	NO <sup>‡</sup>	45 394.58(O)	2347 (approx.)		1888.31	13.88	(22, 24)¶					<sup>2</sup> P <sub>2</sub> — <sup>2</sup> P <sub>2</sub>	
β nitric oxide.....	NO <sup>‡</sup>	52 260(H)	2324	27	1888.31	13.88	(34) <sup>r</sup>						
Green sodium.....	Na <sub>2</sub>	20 301.7(H)	124.13	0.84	158.5	0.73—	(25); c; (15)††	104.7	72.1	2.35	1.95	<sup>1</sup> S— <sup>1</sup> P	(15)
Red sodium.....	Na <sub>2</sub>	15 006.7(H)	115.7	0.43	157.8	0.54	(15)††					<sup>1</sup> S— <sup>2</sup> P	
Sodium hydride (λ4333).....	NaH	23 099(O)					(27) <sup>r</sup>	3.597	5.111	1.503	1.791		(27)
Sodium hydride (λ4655).....	NaH	21 544(O)					(27) <sup>r</sup>	3.206	4.067	1.419	1.598		(27)
Oxygen, atmospheric.....	O <sub>2</sub>	13 122.97(O)	1415.017	11.911—			(9)¶¶	{ 19.928	19.262	1.229	1.208	<sup>2</sup> S— <sup>1</sup> S(?)	(9) <sup>b</sup>
Oxygen, Schumann-Runge.....	O <sub>2</sub>	13 124.87(O)	708	12.4—	1565.37	11.375	(1) <sup>r</sup>	{ 19.757	19.143	1.223	1.204	<sup>2</sup> S— <sup>2</sup> S(?)	(1)
Oxygen, first negative.....	O <sub>2</sub> <sup>+</sup>	38 308††(H)	885.2	13.7	1859.9¶¶	16.53	(1)					<sup>2</sup> P— <sup>2</sup> P	
Oxygen, second negative.....	O <sub>2</sub> <sup>+</sup> (?)	38 108††(H)	1180.3	17.8	1026.1	11.1	(37, 38)¶¶						
Water vapor.....	OH	16 592.2(H)	3084.7	97.8	(3568.4)		(1, 23)	1.634	1.500	1.022	0.979	<sup>2</sup> P— <sup>2</sup> S	(1)***
Sulfur.....	S <sub>2</sub>	32 140(H)	424.4	2.7	724.5	2.91	(44)						
Sulfur oxide.....	SO	36 890(H)	623	6	1094.6	6.3	(37, 38)						

\* By a different analysis (42),  $r = 16\ 103 + 74\pi' - 90\pi''$ .

† Changed to O. M.; Mecke (37, 38) gives values in N. M.

‡ Constants of (1) revised to agree with numbering of (41.6).

§ In spite of apparent numerical discrepancies, all 4 of NO systems have the same lower level.

¶ Values of  $r'_0$  extrapolated from Guillery's  $r'_2, r'_3, r'_4$ .¶¶  $r_0$  is mean of doublet;  $\omega''_0$  and  $\omega''_x$  are from  $\gamma$ -bands.\*\*\*  $r_0$  is mean of doublet.

†† Origin and head almost coincide.

‡‡ Data poor; lower level same as for green band.

§§ Lower level same as for Schumann-Runge bands.

||| Undoubtedly too small, see (1).

¶¶ Origin and analysis very uncertain, see (38).

\*\*\* These values of  $r'_0$  and  $r''_0$  correct an accidental error in (1); see also (31).



TABLE 1.—(Continued)

Name of band	Carrier	Shaded	$\nu$	Upper		Lower		Lit	Upper, $I'_0$	Lower, $I'_0$	Upper, $r'_0$	Lower, $r'_0$	Type	Lit.
				$\omega'_0$	$\omega'_0 x'$	$\omega''_0$	$\omega''_0 x''$							
Scandium oxide.....	ScO	R	$\left\{ \begin{array}{l} 16\ 561(\text{H}) \\ 16\ 521(\text{H}) \end{array} \right\}$	867	8.7	967	3.8	(37, 38)						
Selenium.....	Se <sub>1</sub>	R	27 307(H)	247.2	2.3	397.5	1.32	(44)						
Silicon fluoride $\alpha$ system.....	Si <sub>12</sub> F(?)	R	22 880.5(H)	709.5	7.05	860.5	4.55	(29)	95.6	95.4	2.261	2.259		(29)
Silicon fluoride $\beta$ system.....	Si <sub>12</sub> F(?)	V	34 561.4(H)	1015.8	4.75	860.5	4.55	(29)						
Silicon nitride A.....	Si <sub>12</sub> N	R	24 234.2(O)	1016.3	17.77+	1145.0	6.57	(1)	38.0	37.4	1.571	1.558	<sup>1</sup> S - <sup>1</sup> S	(39)b
Silicon nitride new.....	SiN(?)	R	$\left\{ \begin{array}{l} 26\ 676(\text{H}) \\ 26\ 649(\text{H}) \end{array} \right\}$	694	3.3	1025.9	6.4	(39)					<sup>1</sup> P - <sup>1</sup> P	
Silicon oxide.....	SiO	R	42 643(H)	844	5.8	1236	6.0	(1)					<sup>1</sup> S - <sup>1</sup> P	
Tin chloride.....	SnCl	V	$\left\{ \begin{array}{l} 31\ 262.5(\text{H}) \\ 33\ 622.6(\text{H}) \end{array} \right\}$	431.3 431.3	1.2 1.2	353.5 351.4	1.0 1.2	(1)					<sup>1</sup> P - <sup>1</sup> S	
Strontium fluoride.....	SrF	V	$\left\{ \begin{array}{l} 15\ 356.3(\text{H}) \\ 15\ 076.6(\text{H}) \end{array} \right\}$	504.6	2.22	497.7	1.85	(37, 38)					<sup>1</sup> S - <sup>1</sup> P	
Strontium fluoride.....	SrF	R	17 302.6(H)	487.1	1.91	497.7	1.85	(37, 38)						
Strontium oxide.....	SrO	R	24 638(H)	516	3	648	3.9	(37, 38)						
Tellurium.....	Te <sub>1</sub>	R	22 671(H)	163	1	250.4	0.53	(44)						
Titanium oxide (green).....	TiO	R	$\left\{ \begin{array}{l} 19\ 349.34(\text{H}) \\ 19\ 338.61(\text{H}) \end{array} \right\}$	833.3	4.55	1003.6	4.52	(4)						
Vanadium oxide.....	VO	R	17 424(H)	(852)		1008	6	(37, 38)						
Zinc hydride.....	ZnH	V	$\left\{ \begin{array}{l} 23\ 263.6(\text{O}) \\ 23\ 594.0(\text{O}) \end{array} \right\}$			1552		(1)	$\left\{ \begin{array}{l} 3.874 \\ 3.708 \end{array} \right\}$	4.234 4.234	1.538 1.505	1.608 1.608	<sup>1</sup> S - <sup>1</sup> P <sub>1</sub> <sup>1</sup> S - <sup>1</sup> P <sub>2</sub>	(1)



## SYMBOLS AND CONSTANTS.—(Continued from p. 410)

- R Spectral band is degraded towards the red, and usually has sharp head on violet side. For such bands,  $I'_0 > I''_0$ .
- r Nuclear separation of the two atoms.
- $r_0$  Value of  $r$  when vibrational and rotational energies are zero;  $r_0 = \sqrt{I_0/\mu}$ .
- u Symbol for  $2B_0/\omega_0$ .
- V Spectral band is degraded towards the violet, and usually has sharp head on red side. For such bands,  $I'_0 < I''_0$ .
- x A positive constant in equations for vibrational frequency and energy; see  $n$ .
- $\alpha$  A positive constant in  $B = B_0 - \alpha n$ .
- $\lambda$  Wave-length in vacuo. (Either actual or, as in frequency limits, virtual.)
- $\mu$  Symbol for  $m_0 m_1 m_2 / (m_1 + m_2)$ .
- $\nu$  Frequency, or term value, serving to specify an energy level.
- $\nu_0$  A quantity that is experimentally the frequency of a certain line in a certain band, called the "origin of the band system," and is theoretically the spacing of two electronic energy levels.
- $\omega$  Frequency of vibration of the molecule;  $\omega = \omega_0(1 - 2xn + \dots)$ .
- $\omega_0$  Value of  $\omega$  when energies of vibration and rotation are vanishingly small.
- $\approx$  Signifies equivalent to, or corresponding to.

TABLE 2.—ELECTRONIC ENERGY LEVELS OF MULTIPLE LEVEL MOLECULES

In most molecules only a few electronic levels are known, and their relative positions can be readily deduced from Table 1, the vibrational and rotational constants being, within limit of error, the same for each of the correlated systems of bands. Data for more involved cases are given below. The value of  $\sqrt{R/\nu}$  is calculated from ionization potential, if known. In column 1 is given the accepted designation, if any, of the level. Symbols, p. 410 and Table 1. See p. 409. Unit of  $E_0$ ,  $\omega_0$ , and  $\omega_0 x = 1 \text{ cm}^{-1}$ , for  $E_0 \approx 1.965 \times 10^{-16} \text{ erg}$ , for  $\omega_0$  and  $\omega_0 x \approx 2.99796 \times 10^{10} \text{ vibration sec}^{-1}$ ; of  $I_0 = 10^{-40} \text{ g.cm}^2$ ; of  $r_0 = 10^{-8} \text{ cm}$ .

1	$E_0$	$\omega_0$	$\omega_0 x$	$I_0$	$r_0$	Type	$\sqrt{R/\nu}$
BiO (24)*							
X	0	1 873.7	11.71	15.68	1.2074	$^1S$	
A	{ 23 521.3 23 647.5 }	1 248.5	10.6	{ 20.03 19.62 }	{ 1.3647 1.3506 }	$^3P_2$ $^3P_1$	
B	42 865.2	1 270.2	10.07	18.53	1.3128	$^1S$	
CO (19); cf. (2)†							
X	0	2 154.7	12.70			$^1S$	0.9767
a	48 500	1 724.8	14.5			$^3P$	1.2846†
a'	58 927	1 155	9				1.3990
A	64 765	1 499.5	17.24	17.31	1.236	$^1P$	1.4781
b	83 825	(2214)				$^3S$	1.8767
B	86 929	2 132	50	14.26	1.122	$^1S$	1.9778
C	91 923	(2133)				$^1S(?)$	2.1817
c	92 093	(2134)				$^1S(?)$	2.1898
E	92 923						2.2306
F	99 730	1914	198				2.6830
G	105 266						3.3626
X'	114 966	2197	15.17	14.05	1.11	CO+	$\infty$
CO+ (1)							
X'	0	2197	15.17	14.05	1.11	$^1S$	
A'	{ 20 346 20 471.6 }	1550.46	14.07+	17.7(?)	1.25(?)	$^3P_2$ $^3P_1$	
B'	45 637.7	1697.8	24.33	15.4	1.17	$^1S$	
H <sub>2</sub> (3)							
A	0	4262	113.5	0.480	0.76	$^1S$	0.9396
B	90 083	1825	15.9	1.99	1.55	$^2S$	1.7920
	94 735	2390	73	0.78	0.97	$^2P$	1.9281
	94 906.7	2593.82	68.41	0.965	1.08	$^2S$	1.9337
	95 469					$^2P$	1.9526

TABLE 2.—(Continued)

1	$E_0$	$\omega_0$	$\omega_0 x$	$I_0$	$r_0$	Type	$\sqrt{R/\nu}$
H <sub>2</sub> —(Continued)							
C	99 086	2380	66.5	0.942	1.06		2.0882
	111 427					$^3S$	2.9261
	111 518.1	2306.94	62.94	1.072	1.136	$^3P$	2.9365
	111 656.8	2373.89	12.36(?)			$^3P$	2.9526
	117 169.9	2276.45	63.08	1.089	1.145	$^4P$	3.9395
	117 216.9	2325.6(?)				$^4P$	3.9526
	119 744.2	2251	58(?)	1.135	1.168	$^5P$	4.941
	121 130.2	2229(?)	54(?)	1.130	1.166	$^6P$	5.942
	121 961.0					$^7P$	6.942
	122 498.3					$^8P$	7.942
	124 237	2247	61.4	0.927	1.056	H <sub>2</sub> <sup>+</sup>	$\infty$
He <sub>2</sub> (52, 40b, 47)†							
	0					$^1S$	0.743
	164 287.2	(1731.8)		3.650	1.052	$^2S$	1.788
	166 630.6	(1790.1)		3.62	1.047	$^2S$	1.853
	169 071.8			3.784	1.071	$^2P$	1.928
	184 695.7			3.84	1.079	$^3S$	2.810
	185 794.5	(1643.5)		{ 3.861 3.900 }	{ 1.082 1.087 }	$^3P$	2.928
	186 107.5			{ 3.86 3.89 }	{ 1.08 1.09 }	$^3P$	2.964
	186 508.4			3.666	1.054	$^3D$	3.013
	191 064.6			3.88	1.084	$^4S$	3.818
	191 480.2			{ 3.879 3.976 }	{ 1.084 1.098 }	$^4P$	3.928
	191 609.2	(1627.8)		{ 3.90 3.97 }	{ 1.09 1.10 }	$^4P$	3.965
	193 876					$^5S$	4.812
	194 072.7			{ 3.885 3.989 }	{ 1.085 1.099 }	$^5P$	4.928
	194 140.5			{ 3.86 4.11 }	{ 1.08 1.11 }	$^5P$	4.966
	195 467.2	(1623.8)		{ 3.892 4.121 }	{ 1.086 1.117 }	$^6P$	5.927
	195 505.6			{ 3.86 4.20 }	{ 1.08 1.13 }	$^6P$	5.964
	196 304.1	621.9)		{ 3.892 4.174 }	{ 1.086 1.125 }	$^7P$	6.928
	196 844.0			{ 3.895 4.168 }	{ 1.086 1.124 }	$^8P$	7.928
	197 213.6					$^9P$	8.930
	197 476.2					$^{10}P$	9.928
	198 589					He <sub>2</sub> <sup>+</sup>	$\infty$
N <sub>2</sub> (1, 5, 6, 41.5)**							
X	0	2345.16	14.445			$^1S$	0.895
A	66 260††	1446.46	13.929—			$^3S$	1.246
a	68 957.0	1679.2	13.846—			$^1P$	1.271
B	75 778.6	1718.40	14.437—	16.98	1.212	$^3P$	1.340
b	103 671.7						1.817
c	104 415.6						1.838
C	105 431.7	2018.66	26.047—	15.24	1.149	$^3P$	1.867
D	119 996.6						2.548
X'	136 890	2187.4	16.3	14.41	1.117	N <sub>2</sub> <sup>+</sup>	$\infty$
NO (1, 18, 25, 32, 34)†††							
X	{ 0 121 }	{ 1892.12 1891.98 }	{ 14.424+ 14.454+ }	16.29	1.150	$^1P_1$ $^1P_2$	1.20020 1.20116
A	44 193	2352	13—	14.05	1.068	$^3S$	1.85287
B	{ 45 486.12 45 515.58 }	{ 1029.43 1030.88 }	{ 7.460+ 7.455+ }	24.80	1.418	$^1P_1$ $^1P_2$	1.89154 1.89246
C	52 260	2347 (approx.)					2.143
D	53 271	2824	27				2.190
X'	76 140					NO+	$\infty$

\* In terms of O. M., the origin and nuclear separations are not the same for each isotope; note that here they have essentially the same  $r_0$  but different  $I_0$ . For values in N. M., see (1).

† The upper level (c) of the 3A-bands at 92 093 is apparently different from the absorption level (C) at 91 923. See also Table 1, notes.

‡ At least 5-fold, ranging from 1.2840 to 1.2849.

§ At least 5-fold, ranging from 48 438 to 48 534.

|| Calculated levels.

¶ All absolute values of  $E_0$  for He<sub>2</sub> are extremely uncertain, being based on the extremely doubtful assignment of the  $\lambda 600$  band to  $^1S_0 - ^2S_1$ .

\*\* Ionization potential assumed = 16.9 volt.

†† Assumed on basis of 8.18 volt (4) as corrected by (41.5).

††† Assumed ionization potential = 9.4 volt.



TABLE 3.—HEATS OF DISSOCIATION

$D'$ ,  $D''$  = heat of dissociation of excited, of normal, molecule, as derived from spectroscopic data (see p. 410); many of the values have been recalculated by Birge from the original data.  $D'_c$  = value based in whole or in part on chemical data. Probable error is often great. Each numerical value is the number of volts through which a single electron must run in order to acquire an amount of energy that is equal to the corresponding heat of dissociation. Unit =  $8100 \text{ cm}^{-1}$  per molecule  $\approx 1$  electron volt per molecule =  $2.306 \times 10^4 \text{ g-cal}_{18}$  per g-mole.

	$D'$	$D''$	$D'_c$
AgBr <sup>(13)</sup> .....		2.3*	2.6
AgI <sup>(12)</sup> .....		2.34*	2.0
Br <sub>2</sub> <sup>(33)</sup> .....	0.387	1.96*	2.0
C <sub>2</sub> (?)†.....		7.0	
CN.....		9.5	
CO <sup>(6)</sup> .....		11.2	10.8
CO <sup>+</sup> <sup>(6)</sup> .....		9.8	
Cl <sub>2</sub> <sup>(33)</sup> .....	0.233	2.54*	2.47
CsI <sup>(14, 49)</sup> .....		3.25*	3.34
H <sub>2</sub> <sup>(3, 53)</sup> .....		4.42	4.2
H <sub>2</sub> <sup>+</sup> <sup>(3)</sup> .....		2.6	
HI <sup>(12)</sup> .....		2.9	3.0
HgH.....		0.4	
I <sub>2</sub> <sup>(6)</sup> .....	0.547	1.532*	1.6
ICl <sup>(17.5)</sup> .....	0.30	2.20*	2.20
K <sub>2</sub> <sup>(15)</sup> .....	0.57	0.89*	
KBr <sup>(14)</sup> .....		3.9*	
KCl <sup>(14)</sup> .....		4.5*	
KI <sup>(14)</sup> .....		3.25*	
N <sub>2</sub> <sup>(6, 48)</sup> .....		11.7	11.4
N <sub>2</sub> <sup>+</sup> <sup>(6)</sup> .....		9	
NO <sup>(6)</sup> .....		7.9	8.3
Na <sub>2</sub> <sup>(35)†</sup> .....	0.57	0.98*	
NaBr <sup>(14)</sup> .....		3.9	
NaI <sup>(14, 49)</sup> .....		<3.2	3.0

	$D'$	$D''$	$D'_c$
O <sub>2</sub> <sup>(6)</sup> .....	0.96	7.02*	6.5
O <sub>2</sub> <sup>+</sup> <sup>(6)</sup> .....		6.5	
S <sub>2</sub> <sup>(44)</sup> .....	0.97	4.9	
Se <sub>2</sub> <sup>(44)</sup> .....	0.44	3.6(?)	
Te <sub>2</sub> <sup>(44)</sup> .....	0.42	2.8(?)	

\* Deduced from  $D'$ , see p. 410.

† Carrier of Swan bands.

‡ Green bands. See also (15).

|| Schumann-Runge bands. Value of  $D'$  corrects an error in (6).

## LITERATURE

(For a key to the periodicals see end of volume)

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## MAGNETIC RESOLUTION OF SPECTRAL LINES

P. ZEEMAN

## INTRODUCTION

Symbols used exclusively in the table are explained there; those used in the introduction are as follows,  $\lambda$ ,  $c$ ,  $e$ ,  $h$ ,  $m_0$  having their usual significance (Vol. I, p. 16):

- $\nu$  Wave-number corresponding to  $\lambda$ ,  $\nu = 1/\lambda$ .
- $\pi$  Designates components with electric vector parallel to  $H$ . In other connections, it has its usual significance,  $\pi = 3.14159$ .
- $\sigma$  Designates components other than  $\pi$ -components.
- $E$  Energy level, or term.
- $g$  Landé's splitting factor.
- $H$  Magnetic field intensity.
- $j$  Inner quantum number.
- $k$  Azimuthal quantum number.
- $l$  Azimuthal quantum number,  $l = k - 1$ .
- $m$  Magnetic quantum number.
- $n$  Total (principal) quantum number.
- $N$  Rydberg's series constant.
- $o$  Normal resolution by magnetic field,  $o = eH/4\pi cm_0$ ;  $o/H = 4.695 \times 10^{-5} \text{ cm}^{-1}$  per gauss.
- $R$  Term multiplicity.
- $r$  Rotational quantum number.

In Bohr's theory (33),  $\nu = (E_1 - E_2)/h$ , where  $E_1$  and  $E_2$  are the energy levels of two stationary states. An energy level in an atom is called a term. For a neutral atom, a term sequence is approximately given by  $N/(n + a)^2$ , where  $N$  is characteristic of the atom,  $a$  is an empirical constant, and  $n = 1, 2, 3, \dots$

According to the vector atomic model (98, 123, 124, 125, 126, 186, 219, 231, 238, 239) and the assumption that the moments of momentum of all rotary motions within the atom are quantized, an energy state, or level, is defined by certain quantum numbers:

1. The  $n$  in the term sequence. This was given by Bohr and is related to the size of the electron orbit.

2. The azimuthal quantum number ( $k$ ) is related to the shape of the orbit, and is the moment of momentum of the individual electron in its orbit. If the atom contains more than one electron, the total orbital moment of momentum of the entire group is the quantized vector sum of the individual orbital moments.

Recently,  $k$  has been replaced by  $l = k - 1$ , and the vector sum of the  $l$ 's is quantized and denoted by  $L$ . Terms corresponding to  $l = 0, 1, 2$  are denoted by  $S, P, D$ , respectively, and the corresponding orbits by  $s, p, d$ .

3. The moment of momentum of the spin of each electron on its axis is also quantized and gives the quantum number  $r$ , the unit



quantum being  $\frac{1}{2} (h/2\pi)$ . It is supposed that all electrons within an atom spin in the same plane, but not in the same sense. The resultant moment of momentum of the spin of all the electrons is denoted by  $R$ . The maximum term multiplicity is  $2R + 1$ .

4. The total moment of momentum of the whole atom is  $J = L + R$ . This is the inner quantum number  $j$  of Sommerfeld.

The number of electrons in each orbit defines the configuration of the atom and is indicated thus  $s^2p^2d$ , if there are 2 electrons each in the  $s$ - and  $p$ -orbits, and one in the  $d$ -orbit.

From these quantization rules and Pauli's selection rules, it is possible to predict the spectral structure which corresponds to a given configuration of the atom (100, 101). The general term symbol is a group of the quantum numbers written in the form  $n^k l_j$ , where  $k$  is commonly replaced by the  $S, P, D$  notation, already defined, and whenever  $j$  is an odd number of halves, it is replaced by  $j + \frac{1}{2}$ . The last is for typographical simplicity.

**Effect of External Magnetic Field (262).** 1. *Normal Zeeman Effect.*—Zeeman (250) discovered that a magnetic field ( $H$ ) splits a line into polarized components. When viewed at right angles to  $H$  there are 3 components; the central one ( $\pi$ -component) coincides with the unresolved line, and its electric vector is parallel to  $H$ ; the outer ( $\sigma$ ) components are equidistant from the central one and their electric vectors are perpendicular to  $H$ . When viewed along  $H$  there are only two components; these are in the same positions as the  $\sigma$ -components, and are circularly polarized in opposite directions. Various theoretical explanations have been given (33, 51, 129, 230, 250). On the quantum theory the effect of a magnetic field on a spectral term  $E$  is  $\Delta E = h\omega_m$ , or  $\Delta\nu = \omega_m$ , where, according to the vector model, the magnetic quantum number  $m$  is the projection of  $j$  upon the direction of  $H$ , and  $\omega = eH/4\pi cm_0$  is the normal resolution. In combination with the selection rules and the polarization rule for  $m$  ( $\Delta m = 0$  for  $\pi$ -component,  $\Delta m = \pm 1$  for  $\sigma$ -component) this gives an explanation of the normal Zeeman effect.

2. *Anomalous Zeeman Effect.*—For large values of  $H$ , all lines exhibit the normal effect (183), but in weaker fields most lines are split into a greater number of components. This is known as the anomalous effect, of which there are many types. The type is the same for all lines of a spectral series, and for analogous lines of atoms which exhibit the same spectral structure (192). In every case the Zeeman pattern is quite symmetrical about the center, as to distance, polarization, and intensity, and the distances differ little from rational fractions of the normal resolution  $\omega$  (212). See Fig. 1. Hence the effect may be symbolized thus:  $\pm[(1)(3)579]/5$ , indicating, in this case, that ideally the line is split into 10 components, symmetrical about the center and at distances  $\frac{1}{5}\omega$ ,  $\frac{3}{5}\omega$ ,  $\frac{5}{5}\omega$ , and  $\frac{9}{5}\omega$  of the normal resolution  $\omega$ ; that the  $\pi$ -components are the first and second, in ( ); and that the strongest components are the first and fifth, printed in bold-face. This symbolism is used in this report; for comparison with observed distances, which are frequently not rational fractions of  $\omega$ , the ratios are expressed decimally.

The formalistic theory of Landé (17) is quite successful in explaining the anomalous effect. On this theory, a magnetic field splits a term into  $2j + 1$  magnetic sublevels having the magnetic quantum numbers  $m = j, j - 1, \dots, 1 - j, -j$ . Generally, the effect is anomalous and  $\Delta\nu = g\omega_m$ , where  $g$ , Landé's splitting factor, measures the spacing of the magnetic sublevels. To represent the observations best,  $g$  must be determined in accordance with the matrix mechanics (99), giving  $g = 1 + [j(j + 1) + r(r + 1) - k(k + 1)]/2j(j + 1)$ . See Table 1.

For many atoms the Zeeman effect deviates markedly from the theoretical pattern so determined,  $g$  having values not given by the formula. These deviations appear to depend upon two factors. They increase with increasing atomic number, and for a given spectrum they are usually small for the lowest level and increase

progressively as the level increases. In such cases it is supposed that the vector coupling is not normal (87). These terms are said to be anomalous. In several cases it is not possible to find the theoretical values of  $g$  for the individual terms, but Pauli (185) has shown that in all cases the sum of the  $g$ -values for all terms of the same  $j$  of a particular configuration is the same as the sum of the theoretical  $g$ -values (principle of permanence of the

## Term Combination

	$\leftarrow \sigma \rightarrow \leftarrow \sigma \rightarrow$	Type
$^1(S_0 P_1)$		$\pm (0) 1$
$^2(S_1 P_1)$		$\pm (2) \frac{4}{3}$
$^2(S_1 P_2)$		$\pm (1) \frac{35}{3}$
$^2(P_1 D_2)$		$\pm (1) \frac{11}{15}$
$^2(P_2 D_2)$		$\pm (4) \frac{8(12) 16 24}{15}$
$^2(P_2 D_3)$		$\pm (0) \frac{(3) 15 17 19 21}{15}$
$^3(S_1 P_0)$		$\pm (0) \frac{4}{2}$
$^3(S_1 P_1)$		$\pm (1) \frac{34}{2}$
$^3(S_1 P_2)$		$\pm (0) \frac{(1) 234}{2}$
$^3(P_0 D_1)$		$\pm (0) \frac{1}{2}$
$^3(P_1 D_1)$		$\pm (2) \frac{3}{2}$
$^3(P_2 D_1)$		$\pm (0) \frac{1(2) 35}{2}$
$^3(P_1 D_2)$		$\pm (0) \frac{2579}{6}$
$^3(P_2 D_2)$		$\pm (2) \frac{(4) 57911}{6}$
$^3(P_2 D_3)$		$\pm (0) \frac{(1) 21678910}{6}$

FIG. 1.—Schematic representation of the types of regular resolution of spectral lines. Dotted lines are  $\pi$ -components. Unit of displacement is that of the  $\sigma$ -components of the  $^1(S_0 P_1)$  lines.

$g$ -sum). All these rules are empirical; for the heavier atoms departures from them are possible and, when they occur, of importance in the interpretation of the mechanics of the atom.



TABLE 1.—VALUES OF LANDÉ'S SPLITTING FACTOR  $g$   
 $g = 1 + [j(j+1) + r(r+1) - k(k+1)]/2j(j+1)$

$j$ $k$	0	1	2	3	4	5	6	7	$\frac{1}{2}$	$\frac{3}{2}$	$\frac{5}{2}$	$\frac{7}{2}$	$\frac{9}{2}$	$\frac{11}{2}$	$\frac{13}{2}$	$\frac{15}{2}$	$\frac{17}{2}$
0	8								2								
1	1								$\frac{1}{2}$	$\frac{3}{2}$							
2		1							$\frac{1}{2}$	$\frac{3}{2}$	$\frac{5}{2}$						
3			1						$\frac{1}{2}$	$\frac{3}{2}$	$\frac{5}{2}$	$\frac{7}{2}$					
4				1					$\frac{1}{2}$	$\frac{3}{2}$	$\frac{5}{2}$	$\frac{7}{2}$	$\frac{9}{2}$				
0		2							2								
1	8	$\frac{3}{2}$	$\frac{1}{2}$						$\frac{3}{2}$	$\frac{5}{2}$	$\frac{7}{2}$						
2		$\frac{3}{2}$	$\frac{1}{2}$	$\frac{1}{2}$					0	$\frac{3}{2}$	$\frac{5}{2}$	$\frac{7}{2}$	$\frac{9}{2}$				
3			$\frac{3}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$			$\frac{3}{2}$	$\frac{5}{2}$	$\frac{7}{2}$	$\frac{9}{2}$	$\frac{11}{2}$				
4				$\frac{3}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$		$\frac{3}{2}$	$\frac{5}{2}$	$\frac{7}{2}$	$\frac{9}{2}$	$\frac{11}{2}$	$\frac{13}{2}$			
0			2						2								
1		$\frac{3}{2}$	$\frac{1}{2}$	$\frac{1}{2}$					$\frac{3}{2}$	$\frac{5}{2}$	$\frac{7}{2}$						
2		$\frac{3}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$				$\frac{3}{2}$	$\frac{5}{2}$	$\frac{7}{2}$	$\frac{9}{2}$	$\frac{11}{2}$				
3		0	1	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$			-1	$\frac{3}{2}$	$\frac{5}{2}$	$\frac{7}{2}$	$\frac{9}{2}$	$\frac{11}{2}$	$\frac{13}{2}$		
4			$\frac{3}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$		0	$\frac{3}{2}$	$\frac{5}{2}$	$\frac{7}{2}$	$\frac{9}{2}$	$\frac{11}{2}$	$\frac{13}{2}$	$\frac{15}{2}$	
0				2					2								
1			$\frac{3}{2}$	$\frac{1}{2}$	$\frac{1}{2}$				$\frac{3}{2}$	$\frac{5}{2}$	$\frac{7}{2}$						
2			3	2	$\frac{1}{2}$	$\frac{1}{2}$			$\frac{3}{2}$	$\frac{5}{2}$	$\frac{7}{2}$	$\frac{9}{2}$					
3		0	$\frac{3}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$		4	2	$\frac{3}{2}$	$\frac{5}{2}$	$\frac{7}{2}$	$\frac{9}{2}$	$\frac{11}{2}$	$\frac{13}{2}$	
4		-1	$\frac{3}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	-1	$\frac{3}{2}$	$\frac{5}{2}$	$\frac{7}{2}$	$\frac{9}{2}$	$\frac{11}{2}$	$\frac{13}{2}$	$\frac{15}{2}$	
$\Delta v =$	1	2	3	4	5	6	7		$\frac{1}{2}$	$\frac{3}{2}$	$\frac{5}{2}$	$\frac{7}{2}$	$\frac{9}{2}$	$\frac{11}{2}$	$\frac{13}{2}$	$\frac{15}{2}$	$\frac{17}{2}$

TABLE 2.—BIBLIOGRAPHIC INDEX OF ELEMENTS FOR WHICH THE  
ZEEMAN EFFECT HAS BEEN INVESTIGATED

The atomic number is written as a subscript to the chemical symbol. (The following have not yet (Jan., 1928) been investigated: Ac<sub>89</sub>, As<sub>33</sub>, Cp<sub>71</sub>, Cs<sub>55</sub>, Dy<sub>65</sub>, Em<sub>86</sub>, Er<sub>68</sub>, Eu<sub>63</sub>, Ga<sub>31</sub>, Gd<sub>64</sub>, Ge<sub>32</sub>, Hf<sub>72</sub>, Ho<sub>67</sub>, In<sub>49</sub>, Lu<sub>71</sub>, Ma<sub>43</sub>, Nd<sub>60</sub>, Nt<sub>86</sub>, P<sub>15</sub>, Pa<sub>91</sub>, Po<sub>84</sub>, Pr<sub>59</sub>, Rb<sub>37</sub>, Re<sub>75</sub>, Rn<sub>86</sub>, S<sub>16</sub>, Sa<sub>62</sub>, Se<sub>34</sub>, Ta<sub>73</sub>, Tb<sub>65</sub>, Te<sub>52</sub>, Tu<sub>69</sub>, U<sub>92</sub>, Xe<sub>54</sub>, Yb<sub>70</sub>.)

A <sub>18</sub>	(30, 58, 132, 135, 136, 154)
Ag <sub>47</sub>	(21, 23, 154, 155, 199, 200, 216)
Al <sub>13</sub>	(184, 205, 216)
Au <sub>79</sub>	(1, 95, 136, 154, 155, 169, 194, 199, 200)
B <sub>5</sub>	(188)
Ba <sub>56</sub>	(5, 7, 8, 10, 160, 161, 189, 191, 216, 220)
Be <sub>4</sub>	(10, 106, 107, 188)
Bi <sub>83</sub>	(94, 137, 194, 199, 200, 240)
Br <sub>35</sub>	(30, 113, 206)
C <sub>6</sub>	(68, 72, 154, 155, 205)
Ca <sub>20</sub>	(12, 21, 106, 107, 158, 163, 178, 179, 184, 189, 205, 216, 260)
Cb <sub>41</sub>	(104, 105)
Cd <sub>48</sub>	(2, 7, 8, 44, 65, 109, 137, 154, 155, 158, 177, 178, 179, 184, 190, 191, 198, 204, 205, 208, 210, 216, 221, 222, 232, 240, 251, 252)
Ce <sub>58</sub>	(121, 143)
Cl <sub>17</sub>	(114)
Co <sub>27</sub>	(88, 109, 220)
Cr <sub>24</sub>	(3, 5, 6, 7, 8, 56, 57, 61, 62, 76, 79, 95, 116, 136, 156, 157, 198, 200, 202, 207, 261)
Cu <sub>29</sub>	(1, 10, 22, 61, 62, 95, 136, 154, 155, 165, 169, 191, 199, 200, 216, 228, 251)
F <sub>9</sub>	(35, 36)
Fe <sub>26</sub>	(2, 5, 6, 7, 21, 25, 26, 27, 55, 88, 95, 109, 116, 117, 118, 120, 136, 152, 153, 154, 155, 172, 204, 205, 235, 249, 253, 254, 260)
Gl <sub>4</sub>	(See Be)
H <sub>1</sub>	(30, 31, 45, 46, 47, 48, 49, 53, 54, 63, 66, 154, 155, 176, 183)
He <sub>2</sub>	(30, 50, 89, 90, 93, 132, 133, 134, 154, 155, 159, 164, 165, 183, 201)
Hg <sub>80</sub>	(18, 19, 20, 30, 32, 77, 78, 83, 84, 85, 89, 90, 106, 107, 109, 132, 133, 137, 138, 140, 142, 154, 155, 165, 166, 167, 170, 171, 174, 178, 179, 205, 209, 211, 213, 214, 215, 216, 222, 244, 247, 254, 255, 256, 257, 258, 260)
I <sub>53</sub>	(30, 135, 248)
Ir <sub>77</sub>	(197)

K <sub>19</sub>	(34, 183)
Kr <sub>36</sub>	(132, 133)
La <sub>57</sub>	(220)
Li <sub>3</sub>	(13, 69, 110, 154, 155, 183, 259, 260)
Mg <sub>12</sub>	(1, 2, 12, 43, 44, 59, 106, 107, 154, 155, 158, 169, 178, 179, 198, 204, 205, 208, 210, 216, 237)
Mn <sub>25</sub>	(5, 11, 13, 76, 135, 136, 154, 155, 157, 158, 191, 198, 200)
Mo <sub>42</sub>	(5, 41, 102, 103, 245)
N <sub>7</sub>	(9, 30, 45, 49, 52, 68, 71, 72, 73, 74, 195, 196)
Na <sub>11</sub>	(10, 13, 44, 69, 70, 71, 73, 74, 120, 122, 132, 133, 154, 155, 166, 183, 188, 191, 201, 208, 216, 221, 222, 246, 252, 259, 260, 263)
Nb <sub>41</sub>	(See Cb)
Ne <sub>10</sub>	(14, 132, 133, 165, 168, 173, 201, 236)
Ni <sub>28</sub>	(5, 12, 21, 88, 109, 136, 173, 187, 205, 225, 235, 249)
O <sub>8</sub>	(47, 49, 75, 156, 180, 183)
Os <sub>76</sub>	(160, 161)
Pb <sub>82</sub>	(15, 94, 194, 199, 200)
Pd <sub>46</sub>	(21, 130, 131, 136, 187, 193, 195, 200)
Pt <sub>78</sub>	(97, 139, 151, 197, 200)
Ra <sub>88</sub>	(217)
Rh <sub>45</sub>	(193, 195, 200, 229)
Ru <sub>44</sub>	(150, 193, 195, 226, 227)
Sb <sub>51</sub>	(94, 194, 199, 200)
Sc <sub>21</sub>	(86)
Si <sub>14</sub>	(205)
Sn <sub>50</sub>	(16, 91, 92, 94, 154, 155, 194, 199, 200, 251)
Sr <sub>38</sub>	(106, 107, 158, 163, 189, 216)
Th <sub>90</sub>	(5, 44, 121, 122, 162)
Ti <sub>22</sub>	(5, 7, 8, 25, 115, 116, 117, 118, 198, 200, 218)
Tl <sub>81</sub>	(10, 154, 155, 208, 216, 240)
V <sub>23</sub>	(3, 4, 5, 6, 7, 120, 145, 197, 200)
W <sub>74</sub>	(5, 28, 57, 102, 103, 121, 233)
Yt <sub>39</sub>	(5, 160, 161, 189, 220)
Zn <sub>30</sub>	(2, 7, 44, 59, 65, 67, 73, 74, 109, 154, 155, 158, 177, 178, 179, 184, 191, 198, 204, 205, 208, 210, 216, 221, 222, 232, 240, 241, 242, 243, 249, 251)
Zr <sub>40</sub>	(160, 161)

TABLE 3.—ZEEMAN EFFECT FOR CU, MN, MO, NE, PB, RH, SC, SN,  
V, AND W

For explanation of type notation, see p. 418. Unit of displacement is  $\sigma = eH/4\pi cm_0$ ;  $\sigma/H = 0.04695 \text{ cm}^{-1}$  per kilogauss.  $B =$  broad;  $2B_o$ ,  $2B_c$  = observed, calculated, overall breadth of the resolved line = sum of the displacements of the extreme components;  $d$ ,  $D$  = diffuse, very diffuse;  $f$  = displacement of strongest  $\sigma$ -component from undisturbed line;  $g$ ,  $[g_v]$  = value of  $g$  for the first [second] term named in the term combination given in the "Term" column; Int. = intensity;  $Q_p$  = pseudoquartet;  $r$ ,  $R$ , (in column Int.) = easily, very easily, reversed;  $r$  (in column 4) = completely resolved into all expected components;  $s$ ,  $S$  = sharp, very sharp;  $s_i$ ,  $s_o$  = sharp inside, outside;  $T$ ,  $T_p$  = triplet, pseudo-triplet;  $T_s$  = sharp triplet;  $w$  = weak, but all components could be measured;  $W$  = very weak;  $Z_o$ ,  $Z_c$  = displacements of components as observed, as calculated;  $\pi$ -components (electric vector parallel to  $H$ ) are in ( ); the displacement of the most intense member of each class ( $\pi$ ,  $\sigma$ ) is printed in bold face. Unit of  $\lambda = 1\text{\AA} = 10^{-8} \text{ cm}$ ; of displacement =  $0.04695 \text{ cm}^{-1}/\text{kilogauss}$ .

Cu<sub>29</sub> (22, 228); Int. and  $\lambda$  (64); Terms (228); term structure (22, 223, 224, 228, 234); references are given in column (4)

Int.	$\lambda$	Terms	4	Type
Cu I				
3	5554.94	$^1D_2 - ^1D_2$	(22)	
	$Z_o$ (0.00)		1.88	
	$Z_c$ (0.03)	(0.09) (0.14)	1.29 1.34 1.40 1.46 1.51 1.57	
1	5352.68	$^3F_4 - ^1D_2$	(228)	
	$Z_o$ (0.00)		2.15	
	$Z_c$ (0.29)	(0.86) (1.43)	2.84 2.28 1.72 1.14 0.57 0.00	



Cu<sub>19</sub>—(Continued)

Int.	$\lambda$	Terms	$\lambda$	Type
Cu I.—(Continued)				
8R	5292.55	$^4D'_1 - ^4D_1$	(222)	$Z_0$ (0.00) 1.42; $Z_1$ (0.00) 1.43
200	5218.20	$^3P_1 - ^3D_1$	(222)	
	$Z_0$ (0.00)	1.01		
	$Z_1$ (0.07) (0.20) 1.00 1.14 1.27 1.40			
1d	5200.05	$^3F_2 - ^4D_1$	(222)	
	$Z_0$ (0.00)	0.73		
	$Z_1$ (0.26) (0.77) (1.22) 2.15 1.62 1.12 0.60 0.09			
100	5153.26	$2^3P_1 - 3^3D_1$	(222)	$Z_0$ (0.00) 0.99; $Z_1$ (0.07) 0.73
				0.87
1	5111.94	$^4D'_1 - ^4D_1$	(222)	$Z_0 = Z_1$ (0.00) 0.00
50	5105.58	$^3D_2 - 2^3P_1$	(222)	
	$Z_0$ (0.00)	1.10		
	$Z_1$ (0.07) (0.20) 1.00 1.14 1.27 1.40			
2	5016.63	$^4D'_1 - ^4D_1$	(222)	$Z_0$ (0.54) 1.63 0.54; $Z_1$ (0.60)
				1.80 0.60
1	4797.07	$^4F_2 - ^4D_1$	(222)	
	$Z_0$ (0.00)	2.06		
	$Z_1$ (0.20) (0.60) (1.00) 2.43 2.03 1.63 1.23 0.83 0.43			
1d	4767.5	$^3D_2 - ^3D'_1$	(222)	$Z_0$ (0.00) 0.69; $Z_1$ (0.00) 0.80
	4704.60	$^4F_4 - ^4D_1$	(222)	
	$Z_0$ (0.65)	1.42		
	$Z_1$ (0.10) (0.29) (0.48) (0.67) 0.76 0.95 1.14 1.34 1.53 1.72 1.91			
20	4651.13	$^4F_2 - ^4D_1$	(222)	
	$Z_0$ (0.00)	1.30		
	$Z_1$ (0.05) (0.14) (0.24) (0.33) 1.00 1.10 1.19 1.28 1.38 1.48 1.57			
20	4586.97	$^4F_4 - ^4D_1$	(222)	
	$Z_0$ (0.00)	0.88		
	$Z_1$ (0.07) (0.20) (0.33) 0.90 1.04 1.17 1.31 1.41 1.57			
15	4530.84	$2^3P_1 - 3^3S_1$	(222)	$Z_0$ (0.33) 1.00 1.69; $Z_1$ (0.23)
				1.00 1.67
4	4509.40	$^4F_2 - ^4D_1$	(22)	$Z_0$ (0.23) 0.23 0.64; $Z_1$ (0.20)
				0.20 0.60
8	4509.39	$^4F_2 - ^4D_1$	(222)	$Z_0$ (0.21) 0.45; $Z_1$ (0.20) 0.60
				0.20
10	4480.38	$2^3P_1 - 3^3S_1$	(222)	$Z_0$ (0.65) 1.33; $Z_1$ (0.67) 1.33
20	4275.13	$^4P_1 - ^4D_1$	(222)	
	$Z_0$ (0.00)	1.12		
	$Z_1$ (0.09) (0.26) (0.43) 1.00 1.17 1.34 1.52 1.69 1.86			
1d	4253.34	$^4F_4 - ^3D'_1$	(222)	
	$Z_0$ (0.00)	1.14		
	$Z_1$ (0.02) (0.06) (0.10) 1.24 1.30 1.26 1.22 1.18 1.14			
8	4248.97	$^4P_1 - ^4D_1$	(222)	$Z_0$ (1.21) 1.21; $Z_1$ (1.22) 1.22
3	4104.23	$^4P_1 - ^4D_1$	(222)	$Z_0$ (0.87) 2.32 0.87
				$Z_1$ (0.87) 2.60 0.87
100	4062.69	$2^3P_1 - 4^3D_1$	(222)	
	$Z_0$ (0.00)	1.06		
	$Z_1$ (0.07) (0.20) 1.00 1.14 1.27 1.40			
100	4022.67	$2^3P_1 - 4^3D_1$	(222)	$Z_0$ (0.00) 0.82
				$Z_1$ (0.07) 0.73 0.87
2	3648.39	$^3F_2 - ^3G_4$	(222)	
	$Z_0$ (0.00)	1.05		
	$Z_1$ (0.02) (0.05) (0.08) 0.97 0.94 0.91 0.87 0.84 0.81			
10	3621.25	$^4D'_1 - ^4D_1$	(222)	$Z_0$ (0.00) 1.10; $Z_1$ (0.00) 1.20
8	3614.22	$^4D'_1 - ^4D_1$	(222)	$Z_0$ (0.00) 1.43; $Z_1$ (0.00) 1.37
2	3609.30	$^3D_2 - ^3P_1$	(222)	
	$Z_0$ (0.97) 0.00			
	$Z_1$ (0.93) 0.12 1.73			
10	3602.04	$^4D'_1 - ^4D_1$	(222)	$Z_0$ (0.00) 1.48; $Z_1$ (0.00) 1.43
2	3594.02	$^3D_2 - ^3P_1$	(22)	
	$Z_0$ (0.20) (0.60) (1.00) 0.60 1.00 1.40 1.80 2.20			
10	3530.39	$^3D_2 - ^3F_2$	(222)	
	$Z_0$ (0.00)	1.14		
	$Z_1$ (0.11) (0.34) 1.27 1.14 0.91 0.69			
6	3524.24	$^3F_2 - ^3F'_4$	(222)	
	$Z_0$ (0.00)	1.50		
	$Z_1$ (0.12) (0.57) (0.95) 2.19 1.81 1.43 1.05 0.67 0.29			
3	3457.86	$^3D_2 - ^3P_1$	(22)	
	$Z_0$ (0.25) (0.79) 0.33 0.84			
	$Z_1$ (0.27) (0.80) 0.40 0.93 1.47 2.00			
8	3440.52	$^3D_2 - ^3F_2$	(22)	
	$Z_0$ (0.20) (0.60) 0.20 0.80 1.00			
10	3337.85	$^3D_2 - ^3F_4$	(222)	
	$Z_0$ (0.00)	1.22		
	$Z_1$ (0.02) (0.06) (0.10) 1.24 1.30 1.26 1.22 1.18 1.14			

Cu<sub>19</sub>—(Continued)

Int.	$\lambda$	Terms	$\lambda$	Type
Cu I.—(Continued)				
3	3279.82	$^3D_2 - ^3F_2$	(22)	
	$Z_0$ 0.00	1.56	(?)	
	$Z_1$ (0.02) (0.09) 0.94 0.89 0.83 0.77 (?)			
1000r	3273.97	$1^3S_1 - 2^3P_1$	(222)	$Z_0$ (0.66) 1.34; $Z_1$ (0.67) 1.23
1000r	3247.55	$1^3S_1 - 2^3P_1$	(222)	$Z_0 = Z_1$ (0.22) 1.00 1.67
8	3243.16	$^4F_4 - ^4F'_4$	(222)	
	$Z_0$ (0.00)	1.30		
	$Z_1$ (0.05) (0.14) (0.24) (0.33) 1.67 1.57 1.48 1.29 1.19 1.10 1.00			
5	3235.71	$^4F_2 - ^4F'_2$	(222)	
	$Z_0$ 0.61			
	$Z_1$ (0.31) (0.94) 1.97 1.34 0.71 0.09			
4	3208.23	$^3D_2 - ^4D_1$	(22)	
	$Z_0$ (0.19) (0.57)	1.67		
	$Z_1$ (0.28) (0.85) 0.51 1.08 1.66 2.23			
10	3194.10	$^3D_2 - ^4D'_1$	(222)	
	$Z_0$ (0.44)	1.05		
	$Z_1$ (0.20) (0.60) 1.40 1.00 0.60			
3	3156.62	$^3D_2 - ^4D'_1$	(22)	$Z_0$ (0.31) 1.10
				$Z_1$ (0.40) 0.40 1.20
10	3142.43	$^4P_2 - ^4S_2$	(222)	
	$Z_0$ 0.40			
	$Z_1$ (0.13) (0.40) 2.14 1.87 1.60			
20	3108.60	$^4P_2 - ^4F'_4$	(222)	
	$Z_0$ 0.51			
	$Z_1$ (0.22) (0.69) (1.15) 0.01 0.45 0.91 1.37			
6	3093.99	$^3D_2 - ^4D'_1$	(22)	
	$Z_0$ (0.00)	1.78		
	$Z_1$ (0.11) (0.34) (0.57) 0.85 1.08 1.31 1.54 1.77 2.00			
4	3073.80	$^3D_2 - ^3F_2$	(22)	
	$Z_0$ (0.30)	1.10		
	$Z_1$ (0.17) (0.51) (0.86) 1.71 1.37 1.03 0.69 0.34			
8	3073.80	$^3D_2 - ^3F_2$	(222)	
	$Z_0$ 0.64	1.51		
	$Z_1$ (0.19) (0.51) (0.86) 1.71 1.37 1.03 0.69 0.34			
10	3063.42	$^3D_2 - ^3P_2$	(222)	
	$Z_0$ 0.52	1.18		
	$Z_1$ (0.27) (0.80) 1.60 1.06 0.53			
6	3036.10	$^3D_2 - ^3D'_1$	(22)	$Z_0$ (0.42) (?)
				$Z_1$ (0.00) 1.333 (?)
10	3010.84	$^3D_2 - ^4D'_1$	(222)	
	$Z_0$ (0.00)	1.15		
	$Z_1$ (0.09) (0.26) (0.43) 1.63 1.46 1.29 1.12 0.94			
10	2997.36	$^3D_2 - ^3D'_1$	(222)	
	$Z_0$ (0.21) (0.60) 1.85			
	$Z_1$ (0.20) (0.60) 1.80 1.40 1.00 0.60			
20	2961.18	$^3D_2 - ^3F_4$	(222)	
	$Z_0$ (0.00)	1.17		
	$Z_1$ (0.02) (0.09) (0.14) 1.00 1.06 1.12 1.17 1.23 1.29			
8	2882.94	$^3D_2 - ^3P_2$	(222)	
	$Z_0$ (0.00)	1.16		
	$Z_1$ (0.07) (0.20) 1.00 1.14 1.27 1.40			
20	2824.38	$^3D_2 - ^3D'_1$	(222)	$Z_0$ (0.00) 1.23; $Z_1$ (0.00) 1.20
2	2768.89	$^3D_2 - 3^3P_1$	(222)	$Z_0$ (0.00) 0.96
				$Z_1$ (0.07) 0.73 0.87
50R	2618.38	$^3D_2 - 3^3P_1$	(222)	
	$Z_0$ (0.00)	1.12		
	$Z_1$ (0.07) (0.20) 1.00 1.14 1.27 1.40			
5R	2492.14	$^3S_1 - ^4P_1$	(222)	$Z_0$ (0.00) 1.00
				$Z_1$ (0.12) 1.00 1.57
4R	2441.62	$^3S_1 - ^4P_1$	(22)	$Z_0$ (0.00) 2.27; $Z_1$ (0.33) 2.33
2	2369.88	$^3D_2 - 4^3F_2$	(222)	
	$Z_0$ (0.00)	1.13		
	$Z_1$ (0.02) (0.09) 0.94 0.89 0.83 0.77			
2R	2263.09	$^3D_2 - ^3P'_1$	(222)	$Z_0$ (0.00) 0.70
				$Z_1$ (0.07) 0.73 0.87
	2230.07	$^3D_2 - ^3F'_4$	(222)	
	$Z_0$ (0.00)	1.05		
	$Z_1$ (0.02) (0.09) (0.14) 1.00 1.06 1.12 1.17 1.23 1.29			
2R	2227.74	$^3D_2 - ^3F'_2$	(222)	
	$Z_0$ (0.00)	0.79		
	$Z_1$ (0.02) (0.09) 0.94 0.89 0.83 0.77			
2R	2215.65	$^3D_2 - ^3D'_1$	(222)	$Z_0$ (0.00) 0.96
				$Z_1$ (0.00) 0.80
2R	2214.56	$^3D_2 - ^3P_1$	(222)	
	$Z_0$ (0.00)	1.18		
	$Z_1$ (0.07) (0.20) 1.00 1.14 1.27 1.40			
2R	2199.65	$^3D_2 - ^3D_1$	(222)	$Z_0$ (0.00) 1.17
				$Z_1$ (0.00) 1.20



Mn<sub>25</sub> (11); Int. and λ (11); cf. (112); Terms (11, 37); in column (4) are notes and symbols

Int.	λ	Terms	4	Type
Mn I				
10R	4823.522	<sup>3</sup> P <sub>2</sub> - <sup>3</sup> S <sub>4</sub>	r	[(1) (3) (5) (7) 9 11 13 15 17 19 21 23]/9
	Z <sub>0</sub> (0.1108) (0.3324) (0.5540) (0.7756)	0.9973	1.219 1.441 1.662 1.884	
	Z <sub>0</sub> (0.111) (0.333) (0.555) (0.778)	1.00	1.22 1.44 1.66 1.89	
	2.11 2.33 2.55			
9R	4783.432	<sup>3</sup> P <sub>2</sub> - <sup>3</sup> S <sub>4</sub>	*†	[(2) (6) (10) (14) 112 116 120 124 128 132 136]/63
	Z <sub>0</sub> (0.211) 1.785 1.845 1.905 1.966 2.026 2.087			
	2.147			
	Z <sub>0</sub> (0.033) (0.095) (0.158) (0.222) 1.778 1.840 1.904 1.968 2.031 2.094			
	2.158			
9R	4754.058	<sup>3</sup> P <sub>2</sub> - <sup>3</sup> S <sub>4</sub>	r	[(1) (3) (5) 9 11 13 15 17 19]/7
	Z <sub>0</sub> (0.143) (0.429) (0.716) 1.278 1.565 1.851 2.173			
	Z <sub>0</sub> (0.143) (0.429) (0.715) 1.286 1.572 1.857 2.143 2.429 2.175			
2	4312.546	<sup>3</sup> P <sub>2</sub> - <sup>3</sup> D <sub>3</sub>	r	[(1) (3) 5 7 9 11]/5
	Z <sub>0</sub> (0.204) (0.618) 1.385 1.797 2.209			
	Z <sub>0</sub> (0.2) (0.6) 1.0 1.4 1.8 2.2			
3	4284.084	<sup>3</sup> P <sub>2</sub> - <sup>3</sup> D <sub>3</sub>	r	[(13) 13 39]/15
	Z <sub>0</sub> (0.861) 0.861 2.578; Z <sub>0</sub> (0.867) 0.867 2.601			
9	4281.097	<sup>3</sup> P <sub>2</sub> - <sup>3</sup> D <sub>3</sub>	r	[(4) (12) (20) 36 44 52 60 68]/35
	Z <sub>0</sub> (0.1113) (0.3375) (0.5637) 1.030 1.256 1.482 1.709 1.935			
	Z <sub>0</sub> (0.1143) (0.3429) (0.5718) 1.029 1.257 1.486 1.714 1.943			
9	4265.920	<sup>3</sup> P <sub>2</sub> - <sup>3</sup> D <sub>3</sub>	r	[(4) (12) 14 22 30]/15
	Z <sub>0</sub> (0.794) 0.926 1.456 1.986			
	Z <sub>0</sub> (0.2667) (0.800) 0.933 1.466 2.00			
8	4257.653	<sup>3</sup> P <sub>2</sub> - <sup>3</sup> D <sub>3</sub>	†	[(4) 4]/3
	Z <sub>0</sub> (1.232) 1.232; Z <sub>0</sub> (1.233) 1.233			
7	4239.723	<sup>3</sup> P <sub>2</sub> - <sup>3</sup> D <sub>3</sub>	r	[7 (11) 29]/15
	Z <sub>0</sub> 0.4623 (0.7356) 1.895; Z <sub>0</sub> 0.467 (0.733) 1.933			
10	4235.306	<sup>3</sup> P <sub>2</sub> - <sup>3</sup> D <sub>3</sub>	r‡	[(3) (9) (15) 25 41 47 53 59 65]/35
	Z <sub>0</sub> (0.0968) (0.2595) (0.4325) 0.998 1.168 1.341 1.514			
	Z <sub>0</sub> (0.0987) (0.257) (0.429) 1.00 1.171 1.343 1.514 1.686 1.857			
8	4235.125	<sup>3</sup> P <sub>2</sub> - <sup>3</sup> D <sub>3</sub>	r	[(17) (51) 93 127 161 195]/105
	Z <sub>0</sub> (0.163) (0.489) 0.890 1.216 1.542 1.868			
	Z <sub>0</sub> (0.163) (0.486) 0.886 1.210 1.533 1.856			
6	4083.639	<sup>3</sup> D <sub>3</sub> - <sup>3</sup> D <sub>3</sub>	¶	[(77) (231) (385) 8115 3269 3423 3577 3731 3785]/2205
	Z <sub>0</sub> (0) 1.488			
6	4082.947	<sup>3</sup> D <sub>3</sub> - <sup>3</sup> D <sub>3</sub>	T <sub>2</sub> †	[(11) (33) 141 163 185 207]/105
	Z <sub>0</sub> (0.1040) (0.312) 1.230 1.583 1.746 1.954			
	Z <sub>0</sub> (0.106) (0.314) 1.248 1.553 1.762 1.972			
6	4079.428	<sup>3</sup> D <sub>3</sub> - <sup>3</sup> D <sub>3</sub>	**	[(11) 17 39]/15
	Z <sub>0</sub> (0.723) 1.120 2.578; Z <sub>0</sub> (0.723) 1.123 2.600			
6	4079.245	<sup>3</sup> D <sub>3</sub> - <sup>3</sup> D <sub>3</sub>	T <sub>2</sub>	[(1) (3) (5) (7) 91 93 95 97 99 101 103 105]/63
	Z <sub>0</sub> (0) 1.490			
2	4070.280	<sup>3</sup> D <sub>3</sub> - <sup>3</sup> D <sub>3</sub>	T <sub>2</sub>	[(0) 10]/3; Z <sub>0</sub> (0) 3.343; Z <sub>0</sub> (0.00) 3.333
2	4068.029	<sup>3</sup> D <sub>3</sub> - <sup>3</sup> D <sub>3</sub>	T <sub>2</sub>	[(0) 28]/15; Z <sub>0</sub> (0) 1.867; Z <sub>0</sub> (0) 1.866
4	4063.553	<sup>3</sup> D <sub>3</sub> - <sup>3</sup> D <sub>3</sub>	T <sub>2</sub>	[(0) 58]/35; Z <sub>0</sub> (0) 1.652; Z <sub>0</sub> (0) 1.657
2	4058.936	<sup>3</sup> D <sub>3</sub> - <sup>3</sup> D <sub>3</sub>	r	[(11) 17 39]/15
	Z <sub>0</sub> (0.723) 1.123 2.598; Z <sub>0</sub> (0.723) 1.133 2.600			
8	4055.553	<sup>3</sup> D <sub>3</sub> - <sup>3</sup> D <sub>3</sub>	T <sub>2</sub>	[(0) 100]/63; Z <sub>0</sub> (0) 1.580; Z <sub>0</sub> (0) 1.587
4	4048.760	<sup>3</sup> D <sub>3</sub> - <sup>3</sup> D <sub>3</sub>	r	[(11) (33) 141 163 185 207]/105
	Z <sub>0</sub> (0.1025) (0.3075) 1.248 1.550 1.775 1.960			
	Z <sub>0</sub> (0.106) (0.314) 1.249 1.553 1.762 1.972			
10	4041.366	<sup>3</sup> D <sub>3</sub> - <sup>3</sup> D <sub>3</sub>	T <sub>2</sub>	[(0) 14]/9; Z <sub>0</sub> (0) 1.554; Z <sub>0</sub> (0) 1.555
5	4035.730	<sup>3</sup> D <sub>3</sub> - <sup>3</sup> D <sub>3</sub>	T <sub>2</sub>	[(77) (231) (385) 8115 3269 3423 3577 3731 3785]/2205
	Z <sub>0</sub> (0) 1.501			
9R	4034.489	<sup>3</sup> S <sub>2</sub> - <sup>3</sup> P <sub>2</sub>	r	[(1) (3) 7 9 11 13]/5
	Z <sub>0</sub> (0.1997) (0.5991) 1.412 1.811 2.210 2.609			
	Z <sub>0</sub> (0.2) (0.6) 1.4 1.8 2.2 2.6			
9R	4033.074	<sup>3</sup> S <sub>2</sub> - <sup>3</sup> P <sub>2</sub>	††	[(2) (6) (10) 60 64 68 72 76]/35
	Z <sub>0</sub> (0.251) 1.700 1.830 1.948 2.070 2.190			
	Z <sub>0</sub> (0.0571) (0.1714) (0.2949) 1.714 1.829 1.949 2.067 2.172			

Mn<sub>25</sub>—(Continued)

Int.	λ	Terms	4	Type
Mn I—(Continued)				
10R	4030.760	<sup>3</sup> S <sub>2</sub> - <sup>3</sup> P <sub>2</sub>	r	[(1) (3) (5) 7 9 11 13 15 17]/7
	Z <sub>0</sub> (0.142) (0.426) (0.710) 0.994 1.278 1.562 1.846 2.130 2.414			
	Z <sub>0</sub> (0.143) (0.429) (0.715) 1.000 1.287 1.573 1.862 2.145 2.434			
8	4018.108	<sup>3</sup> D <sub>3</sub> - <sup>3</sup> D <sub>3</sub>	T <sub>2</sub>	[(1) (3) (5) (7) 91 93 95 97 99 101 103 105]/63
	Z <sub>0</sub> (0) 1.505			
	3843.985	<sup>3</sup> D <sub>3</sub> - <sup>3</sup> F <sub>4</sub>	r	[(1) (17) 33]/15
	Z <sub>0</sub> 0.076 (1.128) 2.199; Z <sub>0</sub> 0.067 (1.123) 2.20			
	3841.081	<sup>3</sup> D <sub>3</sub> - <sup>3</sup> F <sub>4</sub>	r	[(29) 51 (87) 109 167 225]/105
	Z <sub>0</sub> (0.2794) 0.4831 (0.8316) 1.037 1.592 2.146			
	Z <sub>0</sub> (0.2762) 0.4857 (0.8286) 1.038 1.590 2.143			
	3839.777	<sup>3</sup> D <sub>3</sub> - <sup>3</sup> F <sub>4</sub>	††	[(4) (6)]/3; Z <sub>0</sub> 1.237 (1.987); Z <sub>0</sub> 1.233 (2.000)
8	3834.363	<sup>3</sup> D <sub>3</sub> - <sup>3</sup> F <sub>4</sub>	**	[(287) (861) (1435) 1645 2219 2793 3367 3941 4515]/2205
	Z <sub>0</sub> (0.1297) (0.3891) (0.6485) 0.7393 0.9988 1.258 1.518			
	Z <sub>0</sub> (0.1302) (0.3905) (0.6508) 0.7440 1.006 1.276 1.527 1.787 2.047			
6	3833.864	<sup>3</sup> D <sub>3</sub> - <sup>3</sup> F <sub>4</sub>		[(6) 10 (18) 22 34]/15
	Z <sub>0</sub> (0.398) 0.648 (1.194) 1.444 2.240			
	Z <sub>0</sub> (0.40) 0.666 (1.20) 1.466 2.266			
2	3829.674	<sup>3</sup> D <sub>3</sub> - <sup>3</sup> F <sub>4</sub>	w	[9 (19) 47]/15
	Z <sub>0</sub> 0.605 (1.262) 3.128; Z <sub>0</sub> 0.600 (1.264) 3.128			
5	3823.896	<sup>3</sup> D <sub>3</sub> - <sup>3</sup> F <sub>4</sub>	r	[(6) (18) (30) 28 40 52 64 76]/35
	Z <sub>0</sub> (0.173) (0.520) (0.866) 0.787 1.133 1.479 1.825 2.171			
	Z <sub>0</sub> (0.71) (0.513) (0.857) 0.798 1.142 1.486 1.830 2.174			
9	3823.515	<sup>3</sup> D <sub>3</sub> - <sup>3</sup> F <sub>4</sub>	r	[(53) (159) (265) (371) 633 729 835 941 1047 1153 1259 1365]/693
	Z <sub>0</sub> (0.0764) (0.229) (0.382) (0.535) 0.991 1.053 1.206 1.359 1.512 1.665			
	Z <sub>0</sub> (0.0764) (0.229) (0.382) (0.535) 0.999 1.052 1.205 1.358 1.511 1.664			
	1.817 1.970			
6	3809.599	<sup>3</sup> D <sub>3</sub> - <sup>3</sup> F <sub>4</sub>	r	[(6) (18) (30) (42) 58 70 82 94 106 118 130]/63
	Z <sub>0</sub> (0.1124) (0.2990) (0.4856) (0.6722) 0.940 1.128 1.314 1.501 1.688			
	1.874 2.061			
	Z <sub>0</sub> (0.095) (0.286) (0.476) (0.666) 0.921 1.111 1.302 1.492 1.682			
	1.873 2.063			
10	3806.866	<sup>3</sup> D <sub>3</sub> - <sup>3</sup> F <sub>4</sub>	T <sub>2</sub>	[(6) (18) (30) (42) (54) 100 112 124 136 148 160 172 184 196]/99
3	3790.215	<sup>3</sup> D <sub>3</sub> - <sup>3</sup> F <sub>4</sub>	Q <sub>2</sub>	[(1) (3) (5) 55 57 59 61 63 65]/63
	Z <sub>0</sub> ... (0.586)... 1.480...; Z <sub>0</sub> ... (0.548)... 1.494...			
3	3629.739	<sup>3</sup> P <sub>2</sub> - <sup>3</sup> D <sub>3</sub>	T <sub>2</sub> -	[(1) (3) (5) 55 57 59 61 63 65]/63
	Z <sub>0</sub> (0) 1.769			
	Z <sub>0</sub> (0.029 0.086 0.143) 1.57 1.63 1.69 1.74 1.80 1.86			
4	3623.790	<sup>3</sup> P <sub>2</sub> - <sup>3</sup> D <sub>3</sub>	T <sub>2</sub> -	[(1) (3) 195 197 199 201]/105
	Z <sub>0</sub> (0) 1.885			
	Z <sub>0</sub> (0.0095) (0.0286) 1.857 1.876 1.895 1.914			
4	3619.399	<sup>3</sup> P <sub>2</sub> - <sup>3</sup> D <sub>3</sub>	r	[(7) 29 43]/15
	Z <sub>0</sub> (0.489) 1.931 2.869; Z <sub>0</sub> (0.486) 1.923 2.866			
6	3610.296	<sup>3</sup> P <sub>2</sub> - <sup>3</sup> D <sub>3</sub>	r	[(4) (12) 24 32 40]/15
	Z <sub>0</sub> (0.268) (0.805) 1.621 2.182 2.684			
	Z <sub>0</sub> (0.266) (0.800) 1.600 2.153 2.666			
6	3608.484	<sup>3</sup> P <sub>2</sub> - <sup>3</sup> D <sub>3</sub>	r	[(4) (12) (20) 46 54 62 70 78]/35
	Z <sub>0</sub> (0.115) (0.345) (0.571) 1.319 1.549 1.779 2.009 2.240			
	Z <sub>0</sub> (0.114) (0.343) (0.572) 1.314 1.543 1.771 2.000 2.230			
6	3607.530	<sup>3</sup> P <sub>2</sub> - <sup>3</sup> D <sub>3</sub>	¶¶	[(4) (12) (20) (28) 80 88 96 104 112 120 128]/63
	Z <sub>0</sub> (0.421) 1.308 1.429 1.550 1.671 1.792 1.913			
	2.034			
	Z <sub>0</sub> (0.064) (0.191) (0.317) (0.444) 1.270 1.397 1.523 1.651 1.778 1.904			
	2.031			
3	3595.112	<sup>3</sup> P <sub>2</sub> - <sup>3</sup> D <sub>3</sub>	r	[(19) 19 (29) 45 71 97]/35
	Z <sub>0</sub> (0.2961) 0.828 (1.105) 1.276 2.015 2.754			
	Z <sub>0</sub> (0.271) 0.543 (1.113) 1.235 2.027 2.769			
5	3586.540	<sup>3</sup> P <sub>2</sub> - <sup>3</sup> D <sub>3</sub>	r	[(229) (387) (645) 1085 2513 3171 3825 4485 5145]/2205
	Z <sub>0</sub> (0.145) (0.435) (0.725) 0.9495 1.139 1.429 1.719 2.009 2.299			
	Z <sub>0</sub> (0.149) (0.447) (0.745) 0.942 1.139 1.438 1.736 2.035 2.333			
6	3577.880	<sup>3</sup> P <sub>2</sub> - <sup>3</sup> D <sub>3</sub>	r	[(8) (15) (25) (35) 63 73 83 93 103 113 123 133]/63
	Z <sub>0</sub> (0.0768) (0.2304) (0.3840) (0.5376) 0.9977 1.151 1.304 1.456 1.609			
	1.770			
	Z <sub>0</sub> (0.0753) (0.228) (0.397) (0.555) 1.000 1.150 1.317 1.476 1.635			
	1.794			



Mn<sub>25</sub>—(Continued)

Int.	$\lambda$	Terms	4	Type
<b>Mn I.—(Continued)</b>				
9R	2801.076	$^4S_1 - ^4P_1$		[(1) (3) 7 9 11 13]/5
	Z <sub>e</sub> (0.199) (0.597) 1.395 1.793 2.191 2.589			
	Z <sub>e</sub> (0.2) (0.6) 1.4 1.8 2.2 2.6			
<b>Mn II</b>				
6	3497.540	$^4P_1 - ^4D_1$	r	[(0) (2) 9 11 13]/6
	Z <sub>e</sub> (0) (0.332) 1.493 1.825 2.157			
	Z <sub>e</sub> (0.0) (0.333) 1.5 1.833 2.166			
8	3495.840	$^4P_1 - ^4D_0$	T	[(0) 5]/2; Z <sub>e</sub> (0) 2.498; Z <sub>e</sub> (0.0) 2.5
8	3488.618	$^4P_1 - ^4D_1$	r	[(2) 3 5]/2
	Z <sub>e</sub> (0.9987) 1.499 2.498; Z <sub>e</sub> (1.0) 1.5 2.5			
7	3482.918	$^4P_1 - ^4D_2$	r	[(2) (4) 7 9 11 13]/6
	Z <sub>e</sub> (0.3312) (0.6624) 1.165 1.496 1.827 2.158			
	Z <sub>e</sub> (0.333) (0.666) 1.166 1.50 1.833 2.167			
8	3460.332	$^4P_1 - ^4D_3$	r	[(0) (2) (4) 5 7 9 11 13]/6
	Z <sub>e</sub> (0.0) (0.329) (0.658) 0.8294 1.159 1.488 1.817			
	Z <sub>e</sub> (0.0) (0.333) (0.666) 0.833 1.166 1.50 1.833 2.167			
9	3441.999	$^4P_1 - ^4D_4$	***	[(0) (1) (2) (3) 6 7 8 9 10 11 12]/6
	Z <sub>e</sub> (0.0) (0.1655) (0.331) (0.4965) 0.9992 1.165 1.330 1.496			
	Z <sub>e</sub> (0.0) (0.166) (0.332) (0.498) 1.00 1.166 1.333 1.50 1.66 1.83 2.00			
10	2949.207	$^4S_2 - ^4P_2$	r	[(0) (1) (2) 3 4 5 6 7]/3
	Z <sub>e</sub> (0) (0.336) (0.672) 0.995 1.331 1.667 2.003			
	Z <sub>e</sub> (0.0) (0.333) (0.667) 1.00 1.333 1.667 2.00 2.333			
9	2939.315	$^4S_2 - ^4P_1$	†††	[(1) (2) 10 11 12 13]/6
	Z <sub>e</sub> (0.331) 1.337 2.01			
	Z <sub>e</sub> (0.167) (0.334) 1.667 1.833 2.00 2.167			
8	2933.066	$^4S_2 - ^4P_1$	r	[(0) (1) 3 4 5]/2
	Z <sub>e</sub> (0) (0.501) 1.490 1.991 2.492			
	Z <sub>e</sub> (0.0) (0.5) 1.5 2.0 2.5			
9	2605.695	$^4S_2 - ^4P_2$	rd	[(0) (1) (2) 4 5 6 7 8]/3
	Z <sub>e</sub> (0.0) (0.347) (0.694) 1.275 1.622 1.969 2.316			
	Z <sub>e</sub> (0.0) (0.333) (0.666) 1.333 1.667 2.00 2.33 2.67			
9	2593.734	$^4S_2 - ^4P_1$	†††	[(2) (4) (6) 17 19 21 23 25 27]/12
	Z <sub>e</sub> (0.495) 1.760 1.920			
	Z <sub>e</sub> (0.167) (0.334) (0.666) 1.417 1.584 1.750 1.916 2.083 2.250			
10	2576.116	$^4S_2 - ^4P_1$	r	[(0) (1) (2) (3) 4 5 6 7 8 9 10]/4
	Z <sub>e</sub> (0) (0.248) (0.496) (0.744) 0.992 1.240 1.488 1.736			
	Z <sub>e</sub> (0.0) (0.25) (0.5) (0.75) 1.0 1.25 1.50 1.75 2.0 2.25 2.5			

\* Very asymmetric; disturbed by preceding line.

† Resolution is complete for  $\sigma$ , but not for  $\pi$ .‡ The  $\pi$ - and  $\sigma$ -components coincide.

§ Disturbed by following line. || Disturbed by preceding line.

¶ All components very broad. \*\* Partial coincidence with following line.

†† Very asymmetric;  $\pi$ -components not completely resolved.

‡‡ Possibly disturbed. §§ Partial coincidence with preceding line.

|| Qualitatively correct, but not measurable.

¶¶ Only the  $\sigma$ -components on short- $\lambda$  side are completely resolved.\*\*\*  $\pi$ -components completely resolved;  $\sigma$ -components are disturbed and only partially resolved.

††† Not completely resolved. ‡‡‡ Disturbed; not completely resolved.

Mo<sub>42</sub> (245); Int. (96);  $\lambda$  (245); cf. (112); spectral structure (39, 111, 148, 245)

<b>Mo I</b>				
	6030.65	$^4P_1 - ^4D_1$	*	[(0) (1) (2) (3) 6 7 8 9 10 11 12]/6
	Z <sub>e</sub> 1.0			
	Z <sub>e</sub> (0) (0.167) (0.333) (0.500) 1.000 1.167 1.333 1.500 1.667 1.833 2.000			
4	5791.88	$^4P_1 - ^4D_1$		[(0) 1 (2) 3 5]/2
	Z <sub>e</sub> (0) 0.503 1.006 1.509 2.515			
	Z <sub>e</sub> (0) 0.500 1.000 1.500 2.500			
4	5751.42	$^4P_1 - ^4D_2$		[(2) (4) 7 9 11 13]/6
	Z <sub>e</sub> (0.332) (0.664) 1.163 1.494 1.826 2.159			
	Z <sub>e</sub> (0.333) (0.667) 1.167 1.500 1.833 2.167			
3	5722.78	$^4P_1 - ^4D_3$	w	[(0) (1) (2) 8 9 10 11 12]/6
	Z <sub>e</sub> (0) (0.17) (0.34) 3.00			
	Z <sub>e</sub> (0) (0.167) (0.333) 1.333 1.500 1.667 1.833 2.000			
4	5689.22	$^4P_1 - ^4D_1$		[(2) 3 5]/2
	Z <sub>e</sub> (0.990) 1.485 2.475; Z <sub>e</sub> (1.000) 1.500 2.500			
4	5650.15	$^4P_1 - ^4D_1$		[(0) (2) 9 11 13]/6
	Z <sub>e</sub> (0) (0.334) 1.505 1.838 2.173			
	Z <sub>e</sub> (0) (0.333) 1.500 1.833 2.167			
4	5632.48	$^4P_1 - ^4D_0$		[(0) 5]/2; Z <sub>e</sub> (0) 2.51; Z <sub>e</sub> (0) 2.50
6	5570.57	$^4S_2 - ^4P_1$		[(0) (1) 3 4 5]/2
	Z <sub>e</sub> = Z <sub>e</sub> = (0) (0.500) 1.500 2.000 2.500			

Mo<sub>42</sub>—(Continued)

Int.	$\lambda$	Terms	4	Type
<b>Mo I.—(Continued)</b>				
6	5533.06	$^4S_2 - ^4P_1$		[(1) (2) 10 11 12 13]/6
	Z <sub>e</sub> (0.168) (0.334) 1.670 1.838 2.006 2.173			
	Z <sub>e</sub> (0.167) (0.333) 1.667 1.833 2.000 2.167			
6	5506.54	$^4S_2 - ^4P_1$		[(0) (1) (2) 3 4 5 6 7]/3
	Z <sub>e</sub> = Z <sub>e</sub> = (0) (0.333) (0.667) 1.000 1.333 1.667 2.000 2.333			
3	4662.94	$^4P_2 - ^4D_2$	†	[(0) (2) (4) 5 7 9 11 13]/6
	Z <sub>e</sub> (0) (0.324) (0.650) 0.809 1.136 1.455 1.780 2.111			
	Z <sub>e</sub> (0) (0.333) (0.667) 0.833 1.167 1.500 1.833 2.167			
3	4626.65	$^4P_2 - ^4D_1$	†	[(0) (1) (2) (3) 6 7 8 9 10 11 12]/6
	Z <sub>e</sub> (0) (0.163) (0.327) (0.488) 0.975			
	Z <sub>e</sub> (0) (0.167) (0.333) (0.500) 1.000 1.167 1.333 1.500 1.667 1.833 2.000			
3	4595.32	$^4P_1 - ^4D_1$		[(2) 3 5]/2
	Z <sub>e</sub> = Z <sub>e</sub> = (1.00) 1.50 2.50			
3	4576.67	$^4P_1 - ^4D_2$		[(2) (4) 7 9 11 13]/6
	Z <sub>e</sub> = Z <sub>e</sub> = (0.333) (0.667) 1.167 1.500 1.833 2.167			
2	4558.29	$^4P_1 - ^4D_0$		[(0) 5]/2; Z <sub>e</sub> = Z <sub>e</sub> = (0) 2.500
3	4524.50	$^4P_1 - ^4D_1$		(1) (2) (3) 7 8 9 10 11 12]/6
	Z <sub>e</sub> (0.166) (0.332) (0.498) 1.163 1.327 1.493 1.660 1.824 1.990			
	Z <sub>e</sub> (0.167) (0.334) (0.500) 1.167 1.333 1.500 1.667 1.833 2.000			
2	4485.15	Z <sub>e</sub> (0) (0.478) (0.957) (1.435) 0 0.478 0.957 1.435 1.914 2.392		
1	4472.20	Z <sub>e</sub> (0) 0.996		
1	4391.70	Z <sub>e</sub> (0) (2.06) 1.03 3.09 5.15		
4	4381.85	Z <sub>e</sub> (0.372) (0.651) (0.929) (1.207) 1.485 1.763 2.041 2.319		
2	4380.49	$^4D_1 - ^4F_1$		[(3) (6) (9) (12) 18 21 24 27 30 33 36 39]/20
	Z <sub>e</sub> 0.6 1.4			
	Z <sub>e</sub> (0.15) (0.30) (0.45) (0.60) 0.90 1.05 1.20 1.35 1.50 1.65 1.80 1.95			
2	4369.25	$^4D_2 - ^4F_1$		[(1) (2) (3) 3 4 5 6 7 8]/4
	Z <sub>e</sub> (0.243) (0.485) (0.730) 0.730 0.970 1.214 1.455 1.700 1.940			
	Z <sub>e</sub> (0.250) (0.500) (0.750) 0.750 1.000 1.250 1.500 1.750 2.000			
3	4350.52	$^4D_2 - ^4F_2$		[(1) (2) (3) 1 2 3 4]/2
	Z <sub>e</sub> (0.500) (0.999) 0.500 0.999 1.499 1.998			
	Z <sub>e</sub> (0.500) (1.000) 0.500 1.000 1.500 2.000			
2	4341.58	Z <sub>e</sub> (0) 0.797		
	4326.90	$^4D_1 - ^4F_1$		[(3) 0 3]/2
	Z <sub>e</sub> (1.503) 0 1.503; Z <sub>e</sub> (1.500) 0 1.503			
3	4326.29	Z <sub>e</sub> (0) (0.343) (0.686) 0 0.343 0.686 1.029 1.372		
1	4296.34	Z <sub>e</sub> (0) 1.051		
3	4294.03	$^4D_0 - ^4F_1$		[(0) 0]; Z <sub>e</sub> = Z <sub>e</sub> = (0) 0
3	4293.42	$^4D_2 - ^4F_2$		[(0) (1) (2) 3 4 5 6 7]/4
	Z <sub>e</sub> (0) (0.252) (0.504) 0.756 1.008 1.260 1.512 1.764			
	Z <sub>e</sub> (0) (0.250) (0.500) 0.750 1.000 1.250 1.500 1.750			
3	4292.37	$^4D_1 - ^4F_2$		[(0) (1) 1 2 3]/2
	Z <sub>e</sub> = Z <sub>e</sub> = (0) (0.500) 0.500 1.000 1.500			
2	4291.40	Z <sub>e</sub> (0) 1.171		
2	4289.58	Z <sub>e</sub> (0) 1.065		
3	4288.82	$^4D_2 - ^4F_1$		[(0) (3) (6) (9) 12 21 24 27 30 33 36]/20
	Z <sub>e</sub> (0) 0.9			
	Z <sub>e</sub> (0) (0.15) (0.30) (0.45) 0.90 1.05 1.20 1.35 1.50 1.65 1.80			
3	4277.49	$^4D_1 - ^4F_1$		[(0) (1) (2) (3) (4) 10 11 12 13 14 15 16 17 18]/10
	Z <sub>e</sub> 1.0			
	Z <sub>e</sub> (0) (0.1) (0.2) (0.3) (0.4) 1.0 1.1 1.2 1.3 1.4 1.5 1.6 1.7 1.8			
2	4269.47	Z <sub>e</sub> (0) 1.200		
	4255.10	Z <sub>e</sub> (0) 1.133		
3	4232.82	Z <sub>e</sub> (0) 1.09	¶	
3	4120.29	Z <sub>e</sub> (0) 1.176	¶	
2	4105.24	Z <sub>e</sub> 0 1.02		
10	3903.11	$^4S_2 - ^4P_1$		[(0) (1) (2) 4 5 6 7 8]/3
	Z <sub>e</sub> = Z <sub>e</sub> = (0) (0.333) (0.667) 1.333 1.667 2.000 2.333 2.667			
2	3901.93	$^4D_1 - ^4D_2$		[(0) 3]/2; Z <sub>e</sub> (0) 1.498
2	3886.98	$^4D_2 - ^4D_2$		[(0) 3]/2; Z <sub>e</sub> (0) 1.507
2	3869.23	$^4D_2 - ^4D_1$		[(0) 3]/2; Z <sub>e</sub> (0) 1.500
10	3864.30	$^4S_2 - ^4P_1$	**	[(1) (2) (3) 21 22 23 24 25 26]/12
	3851.54	$^4D_1 - ^4D_0$	††	[(0) 3]/2; Z <sub>e</sub> (0) 1.460
3	3833.88	$^4D_1 - ^4D_1$		[(0) 3]/2; Z <sub>e</sub> (0) 1.497
3	3829.02	$^4D_1 - ^4D_2$		[(0) 3]/2; Z <sub>e</sub> (0) 1.498
2	3826.85	$^4D_2 - ^4D_1$		[(0) 3]/2; Z <sub>e</sub> (0) 1.499
1	3825.50	Z <sub>e</sub> (0) 0.756		
2	3823.13	$^4D_1 - ^4D_1$		[(0) 3]/2; Z <sub>e</sub> (0) 1.515
10	3798.41	$^4S_2 - ^4P_1$		[(0) (1) (2) 3 4 5 6 7 8 9 10]/4
	Z <sub>e</sub> (0) (0.248) (0.495) (0.743) 0.990 1.238 1.485 1.733 1.980 2.203 2.475			
	Z <sub>e</sub> (0) (0.250) (0.500) (0.750) 1.000 1.250 1.500 1.750 2.000 2.250 2.500			



Mo<sub>42</sub>—(Continued)

Int.	$\lambda$	Terms	4	Type
Mo I.—(Continued)				
2	3797.42	$^3D_0 - ^3D'_1$		[(0) 3]/2; $Z_0$ (0) 1.498
2	3781.78	$^3D_2 - ^3D'_1$		[(0) 3]/2; $Z_0$ (0) 1.464
2	3770.60	$^3D_2 - ^3D_3$		[(0) 3]/2; $Z_0$ (0) 1.501
2	3763.50	$^3D_3 - ^3D_4$		[(0) 3]/2; $Z_0$ (0) 1.490
1	3728.41	$Z_0$ (0) 1.222		
1	3717.04	$Z_0$ (0) 1.060		
3	3695.14	$Z_0$ (0) (0.266) (0.532) 0.055 0.321 0.587 0.853 1.119		
3	3680.81	$Z_0$ (0.963) 1.360 1.568 1.775 1.985 2.194		
2	3677.64	$Z_0$ (0) 1.570		
2	3640.78	$Z_0$ (0) 1.161		
2	3626.36	$Z_0$ (0) 1.500		
2	3612.61	$Z_0$ (0) 1.216		
1	3571.41	$Z_0$ (0) 1.134		
2	3475.19	$Z_0$ (1.116) 1.116 2.232		
	3447.29	$^3D_4 - ^3F_4$		[(0) (1) (2) (3) (4) 10 11 12 13 14 15 16 17 18]/10
$Z_0$ 0.9				
	$Z_0$ (0) (0.1) (0.2) (0.3) (0.4) 1.0 1.1 1.2 1.3 1.4 1.5 1.6 1.7 1.8			
	3443.42	$Z_0$ (0) 1.500		
	3438.97	$Z_0$ (0) 0.776		
	3422.47	$Z_0$ (0) 1.512		
	3404.50	$^3D_3 - ^3F_3$		[(1) (2) (3) 3 4 5 6 7 8]/4
	$Z_0$ (0.263) (0.526) (0.789) 0.789 1.060 1.322 1.590			
	$Z_0$ (0.250) (0.500) (0.750) 0.750 1.000 1.250 1.500 1.750 2.000			
	3384.80	$^3D_3 - ^3F_4$		[(0) (3) (6) (9) 12 21 24 27 30 33 36]/20
$Z_0$ 0.8				
	3382.66	$Z_0$ (0) 1.468		
	3363.98	$^3D_2 - ^3F_3$		[(0) (1) (2) 1 2 3 4 5]/2
	$Z_0$ (0) (0.502) (1.005) 0.502 1.005 1.507 2.010 2.501			
	$Z_0$ (0) (0.500) (1.000) 0.500 1.000 1.500 2.000 2.500			
	3358.26	$^3D_2 - ^3F_2$	††	[(0) (1) (2) 3 4 5 6 7]/4
	$Z_0$ (0) (0.243) (0.487) 0.725 0.965 1.215 1.458 1.700			
	$Z_0$ (0) (0.250) (0.500) 0.750 1.000 1.250 1.500 1.750			
	3347.17	$^3D_0 - ^3F_1$		$Z_0 = Z_0$ (0) 0
	3344.90	$^3D_1 - ^3F_2$		[(0) (1) 1 2 3]/2
	$Z_0$ (0) (0.503) 0.503 1.006 1.509			
	$Z_0$ (0) (0.500) 0.500 1.000 1.500			
	3194.11	$^3S_1 - ^3P'_2$		[(0) (1) (2) 4 5 6 7 8]/3
	$Z_0$ (0) (0.327) (0.647) 1.302 1.615 1.940 2.271 2.591			
	$Z_0$ (0) (0.333) (0.667) 1.333 1.667 2.000 2.333 2.667			
	3132.70	$^3S_1 - ^3P'_4$		[(0) (1) (2) (3) 4 5 6 7 8 9 10]/4
	$Z_0$ (0) (0.252) (0.505) (0.758) 1.010 1.263 1.515 1.768 2.020 2.247 2.525			
	$Z_0$ (0) (0.250) (0.500) (0.750) 1.000 1.250 1.500 1.750 2.000 2.250 2.500			
Mo II				
8½	4433.70	$^3P_1 - ^3D_1$		[(11) 7 29]/15
	$Z_0$ (0.730) 0.464 1.929; $Z_0$ (0.733) 0.466 1.933			
10	4377.92	$^3P_1 - ^3D_1$		[(4) 4]/3
	$Z_0$ (2.672) 2.672; $Z_0$ (2.666) 2.666			
	4363.10	$Z_0$ (0.283) (0.749) 0.433 0.999 1.565 2.131		
2	4328.19	$Z_0$ (0.135) (0.406) 0.677 0.948 1.219 1.390		
10	4279.20	$^3P_1 - ^3D_1$		[(4) (12) 14 22 30]/15
	$Z_0$ (0.270) (0.806) 0.942 1.480 2.022			
	$Z_0$ (0.267) (0.799) 0.933 1.465 2.000			
10	4250.85	$Z_0$ (0.171) (0.514) (0.856) 0.514 0.856 1.199 1.541 1.883		
2	4227.23	$^3P_1 - ^3D_1$		[(13) 13 39]/15
	$Z_0$ (0.885) 0.885 2.655; $Z_0$ (0.866) 0.866 2.600			
2	4147.02	$Z_0$ (0.20) 0.93 1.33		
2	4125.80	$Z_0$ (0) 1.159		
6	4122.52	$Z_0$ (0) 0.716	$T_{PB}$	
5	4119.78	$Z_0$ (0.169) (0.506) (0.843) 0.506 0.843 1.180		
15	3961.61	$Z_0$ (0.099) (0.297) (0.495) 0.829		
6	3786.52	$Z_0$ (0.495) 1.155		
5	3755.63	$Z_0$ (0.108) (0.323) (0.538) 0.753 0.968 1.183 1.398 1.613		
3	3744.55	$Z_0$ (0) 0.986		
6	3742.49	$^3D_2 - ^3F_3$		[(2) (6) 0 4 8]/5
	$Z_0$ (0.396) 1.838 0 0.792 1.584			
	$Z_0$ (0.400) 1.200 0 0.800 1.600			
8	3702.72	$^3D_1 - ^3F_3$		[(1) 1 3]/5
	$Z_0$ (0.204) 0.204 0.612; $Z_0$ (0.200) 0.200 0.600			
10	3692.82	$2f_0 = 1.58$	$T_{PB}$	
15	3688.49	$Z_0$ (0) 1.263	$T_{PB}$	
3	3670.87	$Z_0$ (0.150) 0.150 0.300		
4	3658.41	$Z_0$ 1.227		
4	3652.61	$Z_0$ (0) 1.171		
8	3651.30	$Z_0$ [(0.108) (0.325) (0.541) . . . 1.793]		

Mo<sub>42</sub>—(Continued)

Int.	$\lambda$	Terms	4	Type
Mo II.—(Continued)				
3	3591.84	$Z_0$ (0) 0.618		
2	3528.04	$Z_0$ (0) 1.096		
2	3346.35	$Z_0$ (0) 1.462		
2	3287.35	$Z_0$ (0.696) 2.087		
3	3254.83	$Z_0$ (1.33) 1.133		
3	2965.40	$^3D_4 - ^3F_3$		[(43) (129) (215) 285 371 457 543 629 715]/315
	$Z_0$ (0.136) (0.410) (0.683) . . . 2.270			
	$Z_0$ (0.136) (0.410) (0.683) 0.905 1.178 1.451 1.724 1.997 2.270			
4	2963.92	$^3D_3 - ^3F_3$		[(31) (93) 81 143 205 267]/105
	$Z_0$ (0.296) (0.890) 0.775 1.368 1.962 2.551			
	$Z_0$ (0.295) (0.886) 0.771 1.362 1.954 2.543			
5	2934.41	$^3D_1 - ^3F_1$		[(6) 4]/3; $Z_0 = Z_0$ (2.000) 1.333
4	2930.60	$^3D_2 - ^3F_2$		[(6) (18) 10 22 34]/15
	$Z_0$ (0.398) (1.196) 0.664 1.461 2.258			
	$Z_0$ (0.400) (1.200) 0.667 1.468 2.267			
12	2923.50	$^3D_2 - ^3F_3$	††	[(6) (18) (30) 28 40 52 64 76]/35
	$Z_0$ ( . . . ) 0.803 1.147 1.490 1.835 2.179			
	$Z_0$ ( . . . ) 0.800 1.143 1.486 1.828 2.171			
10	2912.02	$^3D_4 - ^3F_4$		[(6) (18) (30) (42) 58 70 82 94 106 118 130]/63
8	2909.20	$^3D_1 - ^3F_3$		[(17) -1 33]/15
	2896.22	$^3D_3 - ^3F_3$		[(5) (15) (25) (35) (45) 99 109 119 129 139]/99
5	2894.52	$2f_0 = 1.96, 2f_0 = 2.00$ $^3D_3 - ^3F_3$		[(6) (18) (30) (42) (54) 100 112 124 135 148 160 - -]/99
4	2891.10	$2B_0 = 3.96, 2B_0 = 4.2$ $^3D_2 - ^3F_2$		[(29) (87) 51 109 167 225]/105
	$Z_0$ (0.275) (0.825) 0.433 1.033 1.583 2.132			
	$Z_0$ (0.276) (0.829) 0.436 1.038 1.590 2.143			
10	2871.61	$^3D_3 - ^3F_4$		[(41) (123) (185) 235 317 399 481 563 645]/315
12	2848.30	$2f_0 = 1.54, 2f_0 = 1.49$ $^3D_4 - ^3F_3$		[(53) (159) (265) (371) 623 729 835 941 - -]/693
3	2729.71	$2f_0 = 1.70, 2f_0 = 1.798$ $^3P_1 - ^3D_3$		[(13) (39) 19 45 71 97]/35
	$Z_0$ (0.369) 1.108 0.839 1.277 2.014 2.751			
	$Z_0$ (0.371) 1.115 0.843 1.286 2.028 2.771			
10	2701.49	$^3P_1 - ^3D_1$		[(4) (12) 24 32 40]/15
	$Z_0$ (0.267) (0.799) 1.698 2.131 2.664			
	$Z_0$ (0.267) (0.800) 1.600 2.133 2.667			
8	2683.30	$^3P_1 - ^3D_1$		[(7) 29 43]/15
10	2660.69	$^3D_3 - ^3D'_4$		[(1) (3) (5) (7) 91 93 95 97 99 101 103 105]/63
7	2653.47	$2f_0 = 2.85, 2f_0 = 2.88$ $^3D - ^3D'_3$		[(11) (33) (55) 445 489 511 533 555]/315
8	2646.57	$2f_0 = 2.86, 2f_0 = 2.825$ $^3D_2 - ^3D'_2$		[(11) 33 141 163 185 207]/105
7	2636.74	$2f_0 = 2.72, 2f_0 = 2.68$ $^3D_2 - ^3D'_1$		[(11) 17 39]/15
3	2619.40	$Z_0$ (0.734) 1.135 2.604; $Z_0$ (0.733) 1.133 2.600		[(0) 10]/3; $Z_0 = Z_0 = (0)$ (0.333)
5	2602.92	$^3D_1 - ^3D'_1$		[(11) 17 39]/15
4	2593.82	$Z_0$ 0.737 1.139 2.612; $Z_0$ 0.733 1.133 2.600		
6	2586.01	$^3D_2 - ^3D'_2$ $^3D_4 - ^3D_3$		[(11) 33 141 163 185 207]/105
	$2f_0 = 2.64, 2f_0 = 2.68$			
	$2f_0 = 2.6, 2f_0 = 2.88$			

\* Number (21) of components is correct, but components are not measurable.

† Measured components on one side, others obscured by  $\lambda = 4662.11$ .†† Resolution of  $\sigma$ -components is visible, but not measurable.‡ All  $\pi$ -components of same intensity. Type is extraordinarily asymmetric.

|| Components resolved, but not measurable.

¶ Pseudo-type with narrow components.

\*\* Not resolved, but type is qualitatively correct. †† Obscured.

‡‡ Asymmetrically distorted; not completely resolved. §§ From (\*).

||| The inner  $\sigma$ -components are too weak.¶¶ Only the  $\sigma$ -components are resolved.



**Ne<sub>10</sub> (14); Int. and  $\lambda$  (181, 182); Terms (101); letters in column (4) indicate the ground type: type a:  $j_z > j_y$ ,  $g_z < g_y$ ,  $\pm [(0) 1 3 4 5]/2$ ; type b:  $j_z > j_y$ ,  $g_z > g_y$ ,  $\pm [(0) 1 3 4 5]/2$ ; type c:  $j_z = j_y$ ,  $g_z \neq g_y$ ,  $\pm [1 2 3 4 5 6]/2$ ; type d:  $j_z$  or  $j_y = 0$ ,  $g_z = g_y$ ,  $\pm [(0) 4]/2$ .**

Int.	$\lambda$	Terms	4	Type
<b>Ne I</b>				
10	7245.165	$^1P_1 - ^1S_1$	c	[(8) 22 30]/15
	Z <sub>e</sub> (0.515) 1.454 1.979; Z <sub>e</sub> (0.533) 1.467 2.000			
10	7032.410	$^1P_1 - ^1S_1$	a	[(0) (1) 2 3 4]/2
	Z <sub>e</sub> (0) (0.488) 1.013 1.5006 1.988			
	Z <sub>e</sub> (0) (0.500) 1.000 1.500 2.000			
10	6929.465	$^1P_1 - ^1P_2$	b	[(0) (6) 31 37 43]/30
	Z <sub>e</sub> (0) (0.1933) 1.026 1.224 1.423			
	Z <sub>e</sub> (0) (0.200) 1.033 1.233 1.433			
2	6717.042	$^1P_1 - ^1D_1$	c	[(1) 30 31]/30
	Z <sub>e</sub> (0.0442) 0.9908 1.035; $\sigma$ 's not completely resolved			
	Z <sub>e</sub> (0.0333) 1.000 1.033			
9	6678.275	$^1P_1 - ^1D_1$	b	[(0) (8) 31 39 47]/30
	Z <sub>e</sub> (0) (0.260) 1.035 1.297 1.559			
	Z <sub>e</sub> (0) (0.2667) 1.033 1.300 1.567			
15	6598.953	$^1P_1 - ^1P_1$	c	[(9) 31 40]/30
	Z <sub>e</sub> (0.2996) 1.0343 1.335; Z <sub>e</sub> (0.300) 1.033 1.333			
6	6532.881	$^1P_0 - ^1P_1$	d	[(0) 2]/3; Z <sub>e</sub> (0) 0.6639; Z <sub>e</sub> (0) 0.667
15	6506.527	$^1P_1 - ^1D_1$	a	[(0) (5) 12 17 22]/15
	Z <sub>e</sub> (0) (0.3289) 0.8064 1.137 1.468			
	Z <sub>e</sub> (0) (0.333) 0.800 1.133 1.467			
20	6402.246	$^1P_2 - ^1D_1$	a	[(0) (1) (2) 6 7 8 9 10]/6
	Z <sub>e</sub> (0) (0.1643) (0.3286) 0.9951 1.164 1.334 1.503 1.672			
	Z <sub>e</sub> (0) (0.1667) (0.333) 1.000 1.1667 1.333 1.500 1.667			
12	6382.991	$^1P_1 - ^1P_1$	c	[10 (12) 22]/15
	Z <sub>e</sub> 0.6689 (0.7875) 1.469; Z <sub>e</sub> 0.667 (0.800) 1.467			
10	6334.428	$^1P_2 - ^1D_1$	c	[(11) (22) 23 34 45 56]/30
	Z <sub>e</sub> (0.3670) (0.7340) 0.7723 1.139 1.497 1.845			
	Z <sub>e</sub> (0.367) (0.733) 0.767 1.133 1.500 1.867			
6	6304.789	$^1P_1 - ^1P_2$	a	[(0) (7) 30 37 44]/30
	Z <sub>e</sub> (0) (0.2272) 0.9964 1.235 1.473			
	Z <sub>e</sub> (0) (0.233) 1.000 1.233 1.467			
15	6266.495	$^1P_0 - ^1D_1$	d	[(0) 1]/1; Z <sub>e</sub> (0) 0.9937; Z <sub>e</sub> (0) 1.00
15	6217.279	$^1P_2 - ^1P_1$	b	[(0) 4 (5) 9 14]/6
	Z <sub>e</sub> (0) 0.6680 (0.8228) 1.4985 2.329			
	Z <sub>e</sub> (0) 0.667 (0.833) 1.500 2.333			
12	6163.594	$^1P_0 - ^1P_1$	d	[(0) 4]/3; Z <sub>e</sub> (0) 1.339; Z <sub>e</sub> (0) 1.333
12	6143.061	$^1P_2 - ^1P_2$	c	[(8) (16) 29 37 45 53]/30
	Z <sub>e</sub> (0.2718) (0.5436) 0.9646 1.233 1.499 1.768			
	Z <sub>e</sub> (0.2667) (0.5333) 0.9667 1.233 1.500 1.767			
6	6128.457	$^1P_1 - ^1D_1$	c	[(7) 15 22]/15
	Z <sub>e</sub> (0.4730) 0.9860 1.455; Z <sub>e</sub> (0.4667) 1.000 1.467			
8	6096.162	$^1P_1 - ^1D_1$	a	[(0) (5) 34 39 44]/30
	Z <sub>e</sub> (0) (0.1650) 1.123 1.303 1.474			
	Z <sub>e</sub> (0) (0.1667) 1.133 1.300 1.467			
10	6074.337	$^1P_1 - ^1S_0$	d	[(0) 22]/15; Z <sub>e</sub> (0) 1.465; Z <sub>e</sub> (0) 1.467
10	6029.999	$^1P_1 - ^1P_1$	c	[(2) 20 22]/15
	Z <sub>e</sub> (0.1240) 1.333 1.470; Z <sub>e</sub> (0.133) 1.333 1.467			
12	5975.534	$^1P_1 - ^1D_1$	b	[(0) (1) 2 3 4]/2
	Z <sub>e</sub> (0) (0.4902) 1.025 1.516 2.007			
	Z <sub>e</sub> (0) (0.500) 1.000 1.500 2.000			
10	5944.834	$^1P_2 - ^1D_1$	c	[(2) (4) 11 13 15 17]/10
	Z <sub>e</sub> (0.204) (0.409) 1.101 1.304 1.506 1.708			
	Z <sub>e</sub> (0.200) (0.400) 1.100 1.300 1.500 1.700			
20	5881.896	$^1P_2 - ^1P_1$	b	[(0) (1) 8 9 10]/6
	Z <sub>e</sub> (0) (0.1533) 1.349 1.505 1.662			
	Z <sub>e</sub> (0) (0.1667) 1.333 1.500 1.667			
50	5852.487	$^1P_1 - ^1P_0$	d	[(0) 1]/30; Z <sub>e</sub> (0) 1.034; Z <sub>e</sub> (0) 1.033

**Pb<sub>12</sub> (15); spectral structure (81, 82)**

<b>Pb I</b>				
4	5005.45	$2p^1S_0 - 3s^1P_1$	*	[(0) 17]/15; Z <sub>e</sub> (0) 1.112; Z <sub>e</sub> (0) 1.133
3	4168.04	$2p^1D_1 - 3d^1D_1$		[11 (13) 24 (26) 37 50]/30
	Z <sub>e</sub> 0.367 (0.428) 0.796 (0.856) 1.234 1.656			
	Z <sub>e</sub> 0.367 (0.433) 0.800 (0.866) 1.233 1.667			
4	4062.15	$2p^1D_1 - 3d^1D_1$		[(0) (1) 26 37 48]/30
	Z <sub>e</sub> (0) (0.366) 0.865 1.232 1.667			
	Z <sub>e</sub> (0) (0.367) 0.867 1.233 1.600			

**Pb<sub>12</sub>—(Continued)**

Int.	$\lambda$	Terms	4	Type
<b>Pb I—(Continued)</b>				
6	4057.92	$2p^1P_1 - 2s^1P_1$		[(0) (1) 18 19 20]/15
	Z <sub>e</sub> (0) (0.075) 1.194			
	Z <sub>e</sub> (0) (0.067) 1.200 1.267 1.333			
3	4019.62	$2p^1D_1 - 3d^1F_1$		[(0) (7) 14 53 60 67 74 81]/60
	Z <sub>e</sub> (0) (0.102) 0.202 0.913 1.015			
	Z <sub>e</sub> (0) (0.117) 0.233 0.883 1.000 1.117 1.233 1.350			
5	3740.00	$2p^1D_1 - 3s^1P_1$		[(8) (16) 29 37 45 53]/30
	Z <sub>e</sub> (0.269) (0.538) 0.957 1.225 1.490 1.752			
	Z <sub>e</sub> (0.267) (0.533) 0.967 1.233 1.500 1.767			
6	3683.47	$2p^1P_1 - 2s^1P_0$		[(0) 3]/2; Z <sub>e</sub> (0) 1.494; Z <sub>e</sub> (0) 1.500
3	3671.50	$2p^1D_1 - 3s^1P_1$		[(0) (3) 34 37 40]/30
	Z <sub>e</sub> (0) (0.066) 1.149 1.255			
	Z <sub>e</sub> (0) (0.100) 1.133 1.233 1.333			
	Better			[(0) (2) 35 37 39]/30
	Z <sub>e</sub> (0) (0.067) 1.167 1.233 1.300			
6	3639.57	$2p^1P_1 - 2s^1P_1$		[(1) 8 9]/6
	Z <sub>e</sub> (0.166) 1.336 1.502; Z <sub>e</sub> (0.167) 1.333 1.500			
5	3572.77	$2p^1D_1 - 3s^1P_1$		[(0) (3) 34 37 40]/30
	Z <sub>e</sub> (0) (0.113) 1.142 1.239 1.337			
	Z <sub>e</sub> (0) (0.100) 1.133 1.233 1.333			
4	2873.29	$2p^1P_2 - 3d^1D_1$		[(7) (14) 5 12 19 26]/15
	Z <sub>e</sub> (0.477) (0.953) 0.316 0.796 1.269 1.748			
	Z <sub>e</sub> (0.467) (0.934) 0.333 0.800 1.267 1.734			
6	2833.06	$2p^1P_0 - 2s^1P_1$		[(0) 4]/3; Z <sub>e</sub> (0) 1.340; Z <sub>e</sub> (0) 1.333
4	2823.20	$2p^1P_2 - 3d^1F_1$		[(0) (1) (2) 74 75 76 77]/60
	Z <sub>e</sub> (0) 1.260			
	Z <sub>e</sub> (0) (0.017) (0.034) 1.233 1.250 1.267 1.284			
5	2802.01	$2p^1P_2 - 3d^1F_1$		[(0) (9) (18) 49 58 67 76 85]/60
	Z <sub>e</sub> (0) (0.155) (0.310) 0.808 0.962 1.116 1.271			
	Z <sub>e</sub> (0) (0.150) (0.300) 0.817 0.967 1.117 1.267 1.417			
4	2663.17	$2p^1P_2 - 3s^1P_1$		[(7) (14) 31 38 45 52]/60
	Z <sub>e</sub> (0.221) (0.442) 1.039 1.266 1.493 1.719			
	Z <sub>e</sub> (0.233) (0.466) 1.033 1.267 1.500 1.733			
5	2614.20	$2p^1P_1 - 3d^1F_1$		[(0) (1) 4 5 6]/4
	Z <sub>e</sub> (0) (0.249) 0.995 1.246 1.499			
	Z <sub>e</sub> (0) (0.250) 1.000 1.250 1.500			
3	2613.68	$2p^1P_1 - 3d^1D_1$		[(19) 26 45]/30
	Z <sub>e</sub> (0.632) 0.793 1.507; Z <sub>e</sub> (0.633) 0.864 1.500			
4	2577.28	$2p^1P_2 - 3s^1P_1$		[(0) (2) 17 19 21]/15
	Z <sub>e</sub> (0) (0.147) 1.135 1.270 1.420			
	Z <sub>e</sub> (0) (0.133) 1.131 1.267 1.400			
4	2476.39	$2p^1P_1 - 3s^1P_2$		[(0) 3]/2; Z <sub>e</sub> (0) 1.506; Z <sub>e</sub> (0) 1.500
4	2446.20	$2p^1P_1 - 3s^1P_1$		[(1) 8 9]/6
	Z <sub>e</sub> (0.188) 1.307 1.495; Z <sub>e</sub> (0.167) 1.333 1.500			
	(Better) Z <sub>e</sub> (0.200) 1.300 1.500			[(2) 13 15]/10
4	2443.84	$2p^1P_1 - 3s^1P_0$		[(0) 3]/2; Z <sub>e</sub> (0) 1.505; Z <sub>e</sub> (0) 1.500
4	2401.94	$2p^1P_1 - 3s^1P_1$		[(11) 34 45]/30
	Z <sub>e</sub> 0.378 1.126 1.505; Z <sub>e</sub> 0.367 1.133 1.500			
5	2393.80			
<b>Pb II Int. (60)</b>				
10	6660.05			[(2) 4]/3; Z <sub>e</sub> (0.669) 1.340; Z <sub>e</sub> (0.667) 1.333
15	5608.90			[(1) 3 5]/3
	Z <sub>e</sub> (0.336) 0.988 1.656; Z <sub>e</sub> (0.333) 1.000 1.667			
5	2203.41			[(1) 3 5]/3
	Z <sub>e</sub> (0.324) 1.004 1.682; Z <sub>e</sub> (0.333) 1.000 1.667			

\* Deviation 2%.

† Distance of components; the unit is  $\sigma$  = normal resolution.

‡ Distorted, but completely resolved.

§ Reversed in Pb-arc, sharp in Sn-arc.

|| Distorted by  $\lambda = 2613.68$ .

¶ Distorted by  $\lambda = 2614.20$ . Very asymmetric. Calculated type is based on 4062 and 3639, and accords with distorted type of 2613.

\*\* Not resolved; type considered similar to that of 2802.

**Pt<sub>12</sub> (97); Int. (108); Terms (97, 139, 151); terms in ( ) are uncertain**

<b>Pt I</b>		
6	5478.50	Z <sub>e</sub> (0) 1.23
6	5475.78	Z <sub>e</sub> (0.32) 1.26
4	5390.80	Z <sub>e</sub> (0) 1.38
2	5387.88	Z <sub>e</sub> (0.45) 0.88



Pt<sub>78</sub>.—(Continued)

Int.	$\lambda$	Terms	$t$	Type
Pt I.—(Continued)				
4	5368.99	$^1F_2 - (F_2)$	$g_z = 0.92, g_y = 1.19$	
	$Z_o(0)(0.27)(0.55)$		1.73	
	$Z_c(0)(0.27)(0.54)0.650.921.191.46$		<b>1.73</b>	
	5328.60		$Z_o(0)1.03$	
0	5324.59	$^1P_1 - (\bar{D}_2)$	$Z_o(0)1.51$	
0	5319.34		$Z_o(0)1.05$	
6	5301.02		$Z_o(0)1.15$	
3	5260.86	$^1G_4 - (F_2)$	$Z_o(0)0.81$	
0	5257.48		$Z_o(0)1.29$	
6	5227.66	$^1P_1 - (D_2)$	$g_z = 1.19, g_y = 1.37^*$	
	$Z_o(0.36)1.29$			
	$Z_c(0.18)(0.36)1.011.191.371.55$			
	5199.26		$Z_o(0)(1.05)$	
1	5193.91		$Z_o(0)(1.03)$	
	5130.91	$(^1D_1) - (P_0)$	$g_z = 0.50, g_y = 0$	
	$Z_o = Z_c(0)0.50$			
1	5118.44	$^1D_2 - (\bar{D}_2)$	$Z_o(0)1.00$	
	5108.45		$Z_o(0)1.10$	
Od	5095.82		$Z_o(0)1.08$	
	5082.35		$Z_o(0)1.12$	
5	5059.50		$Z_o(0)1.24$	
4	5033.54		$Z_o(0)1.15$	
2	5002.65		$Z_o(0)1.34$	
2	4997.98		$Z_o(0)0.95$	
	4940.15		$Z_o(0)1.15$	
4	4879.55		$Z_o(0.31)1.23$	
0	4862.40		$Z_o(0.33)1.17$	
4	4853.93		$Z_o(0)1.50$	
1	4831.97		$Z_o(0)1.26$	
1	4772.32		$Z_o(0)1.37$	
	4768.12		$Z_o(0)0.79$	
2	4737.50	$^1D_2 - (P_1 \text{ or } \bar{D}_1)$	$g_z = 1.00, g_y = 1.50$	
	$Z_o(0)(0.50)0.501.021.52$			
	$Z_c(0)(0.50)0.501.001.50$			
4	4684.10	$^1F_2 - (\bar{D}_1)$	$g_z = 0.92, g_y = 1.13^*$	
	$Z_o(0)0.86$			
	$Z_c(0)(0.21)0.710.921.13$			
5	4657.95		$Z_o(0)1.46$	
1	4650.07		$Z_o(0)1.15$	
4	4640.82	$(F_2) - (^1D_1)$	$g_z = 0.82, g_y = 0.50^*$	
	$Z_o(0)1.13$			
	$Z_c(0)(0.32)0.500.821.24$			
4	4577.42	$^1F_2 - (\bar{D}_2)$	$g_z = 0.92, g_y = 1.17^*$	
	$Z_o(0.35)1.2$			
	$Z_c(0.21)(0.50)0.670.921.171.42$			
4	4554.59	$^1P_1 - (\bar{D}_2)$	$g_z = 1.42, g_y = 1.40^*$	
	$Z_o(0)1.35$			
	$Z_c(0)(0.02)1.381.401.42$			
5d	4552.42		$Z_o(0.36)1.2$	
5d	4523.00		$Z_o(0)1.23$	
5d	4520.91		$Z_o(0)1.20$	
1	4515.66		$Z_o(0)1.61$	
6	4498.75		$Z_o(0)1.13$	
3	4493.16		$Z_o(0)(0.57)1.121.75$	
2	4486.73		$Z_o(0)1.23$	
5r	4484.72		$Z_o(0)1.20$	
3	4481.64	$^1P_1 - (P_0)$	$g_z = 1.42, g_y = 0$	
	$Z_o = Z_c(0)1.42$			
1	4480.33		$Z_o(0.63)1.29$	
3d	4473.45		$Z_o(0)1.36$	
1	4465.13		$Z_o(0.31)1.24$	
3	4458.65		$Z_o(0)1.04$	
1	4457.06		$Z_o(0)0.92$	
4	4445.56	$^1D_1 - (\bar{D}_2)$	$g_z = 0.45, g_y = 1.37$	
	$Z_o(0)(0.88)0.451.392.21$			
	$Z_c(0)(0.88)0.501.372.24$			
6	4442.52	$^1F_2 - (\bar{D}_2)$	$g_z = 1.03, g_y = 1.37$	
	$Z_o(0)(0.33)(0.68)0.330.681.041.361.69$			
	$Z_c(0)(0.34)(0.68)0.350.691.031.371.71$			
4d	4437.31		$Z_o(0)1.28$	
3	4430.24		$Z_o(0)1.10$	
2	4414.28		$Z_o(0)1.55$	
3	4411.43		$Z_o(0)1.34$	
4	4364.46		$Z_o(0)0.80$	
2d	4358.36		$Z_o(0.22)1.09$	
0	4343.70		$Z_o(0)(0.57)1.151.74$	
2	4334.70		$Z_o(0)0.95$	
4	4327.07		$Z_o(0)1.37$	

Pt<sub>78</sub>.—(Continued)

Int.	$\lambda$	Terms	$t$	Type
Pt I.—(Continued)				
	4309.18		$Z_o(0)1.51$	
	4304.91		$Z_o(0)1.10$	
2	4290.97		$Z_o(0)1.10$	
4	4288.08	$^1F_2 - (F_2)$	$g_z = 0.92, g_y = 0.82$	
	$Z_o(0.23)0.90$			
	$Z_c(0.10)(0.20)0.720.820.921.02$			
1	4281.78	$^1P_2 - (\bar{D}_1)$	$g_z = 1.20, g_y = 1.13^*$	
	$Z_o(0)1.21$			
	$Z_c(0)(0.07)1.131.201.27$			
2	4269.25		$Z_o(0)1.03$	
2	4263.53		$Z_o(0)1.04$	
	4259.97		$Z_o(0)1.57$	
1	4251.16		$Z_o(0)0.88$	
2	4201.14		$Z_o(0)1.06$	
4	4192.43	$^1P_2 - (\bar{D}_2)$	$g_z = 1.20, g_y = 1.17^*$	
	$Z_o(0)1.16$			
	$Z_c(0.03)(0.06)1.141.171.201.23$			
4	4164.54	$^1P_2 - (F_2)$	$g_z = 1.04, g_y = 1.19^*$	
	$Z_o(0.36)0.921.41$			
	$Z_c(0.15)(0.30)(0.45)0.740.891.041.191.341.49$			
5	4118.69		$Z_o(0)(0.60)1.421.67$	
1	4081.48		$Z_o(0)1.29$	
2	4065.94		$Z_o(0.37)1.25$	
2	4054.78		$Z_o(0)1.21$	
	4000.72		$Z_o(0)1.05$	
3	3996.59	$^1F_2 - (\bar{D}_2)$	$g_z = 0.92, g_y = 1.40$	
	$Z_o(0.51)(0.92)0.420.921.411.90$			
	$Z_c(0.49)(0.98)0.430.921.411.90$			
3	3966.35		$Z_o(0.53)1.52$	
1	3953.63		$Z_o(0.75)1.56$	
4	3948.38	$^1P_2 - (F_2)$	$g_z = 1.20, g_y = 0.82$	
	$Z_o(0.34)(0.73)0.731.201.58$			
	$Z_c(0.38)(0.76)0.440.821.201.58$			
4	3925.34		$Z_o(0)1.33$	
5	3922.97		$Z_o(0)1.34$	
3	3910.90		$Z_o(0)1.23$	
2	3906.27		$Z_o(0)1.02$	
4	3898.74		$Z_o(0.36)1.36$	
4	3819.88		$Z_o(0)1.08$	
5	3818.69		$Z_o(0)1.36$	
2	3720.74		$Z_o(0)1.15$	
3	3706.54		$Z_o(0.41)1.04$	
4	3699.89	$^1P_2 - (\bar{D}_1)$	$g_z = 1.20, g_y = 1.40^*$	
	$Z_o(0.44)1.271.61$			
	$Z_c(0.20)(0.40)1.001.201.401.60$			
4	3687.45		$Z_o(0)1.36$	
4	3683.02		$Z_o(0)1.54$	
4	3674.05	$^1D_1 - (\bar{D}_2)$	$g_z = 0.59, g_y = 1.17$	
	$Z_o(0)(0.60)1.151.76$			
	$Z_c(0)(0.58)0.591.171.76$			
4	3672.00		$g_z = 1.04, g_y = 1.17^*$	
	$Z_o(0)1.00$			
	$Z_c(0)(0.13)(0.26)0.780.911.041.171.30$			
1	3668.39		$Z_o(0)0.98$	
4	3663.09		$Z_o(0)1.18$	
1	3652.26		$Z_o(0)1.35$	
6	3643.16		$Z_o(0)1.16$	
6	3638.78		$Z_o(0)1.201.80$	
3	3628.84		$Z_o(0)1.30$	
5	3628.11		$Z_o(0)1.84$	
2	3610.91	$^1F_2 - (P_1 \text{ or } D_1)$	$g_z = 0.92, g_y = 1.50^*$	
	$Z_o(0)1.01$			
	$Z_c(0)(0.48)0.340.821.50$			
3	3587.38	$^1P_1 - (P_0)$	$g_z = 1.50, g_y = 0$	
	$Z_o(0)1.49; Z_c(0)1.50$			
6	3485.27	$^1D_1 - (F_2)$	$g_z = 0.49, g_y = 0.87$	
	$Z_o(0)(0.38)0.881.25$			
	$Z_c(0)(0.88)0.490.871.25$			
5	3483.42	$^1P_2 - (F_2)$	$g_z = 1.04, g_y = 0.87^*$	
	$Z_o(0)1.43$			
	$Z_c(0)(0.17)(0.34)0.700.871.041.211.38$			
4	3464.43		$Z_o(0)0.81$	
	3427.94		$Z_o(0)1.16$	
	3421.72		$Z_o(0.29)1.02$	
2	3417.05		$Z_o(0)0.87$	
4	3343.90		$Z_o(0)0.48$	
6	3323.80		$Z_o(0)1.60$	
4	3315.03		$Z_o(0)1.72$	



Pt<sub>78</sub>.—(Continued)

Int.	$\lambda$	Terms	4	Type
Pt I.—(Continued)				
6	3290.20	$^1D_1 - (\bar{D}_1)$		$g_z = 0.51, g_y = 1.39$
	$Z_o(0)(0.88)$	1.36 <b>2.37</b>		
	$Z_o(0)(0.88)$	0.51 1.39 <b>2.37</b>		
4	3268.38			$Z_o(0) 1.28$
4	3261.67			$Z_o(0) 1.00$
2	3261.08			$Z_o(0) 1.29$
4	3259.72			$Z_o(0) 0.93$
6	3255.93	$^1S_0 - (\bar{D}_1)$		$g_z = 0, g_y = 1.13$
	$Z_o = Z_o = (0) 1.13$			
5	3251.97	$^1D_1 - (P_0)$		$g_z = 0.46, g_y = 0$
	$Z_o = Z_o = (0) 0.46$			
4	3250.33			$Z_o(0) 1.39$
5	3240.20			$Z_o(0) 1.03$
5	3230.29			$Z_o(0) 1.17$
6	3204.06			$Z_o(0) 1.31$
4	3200.69			$Z_o(0) 1.13$
5	3156.56	$^1D_1 - (P_1)$		$g_z = 0.50, g_y = 1.10$
	$Z_o(0.60)$	1.10		
	$Z_o(0.60)$	0.50 1.10		
6R	3064.69	$^1D_1 - (\bar{D}_1)$		$g_z = 1.33, g_y = 1.37^*$
	$Z_o(0)$	1.25		
	$Z_o(0)(0.02)(0.04)$	1.30 1.32 1.33 1.35 1.37		
4R	3042.63			$Z_o(0) 1.61$
7R	2997.97	$^1D_1 - (F_1)$		$g_z = 1.00, g_y = 1.19^*$
	$Z_o(0)(?)$	1.15		
	$Z_o(0)(0.19)(0.38)$	0.81 1.00 1.19 1.38 <b>1.57</b>		
4	2989.80			$Z_o(0) 1.45$
2	2983.74			$Z_o(0.72) 2.13$
4	2959.09			$Z_o(0) 1.59$
8R	2929.79			$Z_o(0) 1.64$
3	2921.40			$Z_o(0) 1.39$
4	2919.35	$^1P_1 - (F_1)$		$g_z = 1.20, g_y = 1.19$
	$Z_o(0)$	1.16		
	$Z_o(0)(0.30)$	0.90 1.20 1.50		
4	2913.57			$Z_o(0)(0.82) 2.02$
2	2913.30			$Z_o(0) 1.11$
4	2905.90			$Z_o(0) 1.10$
5	2897.89			$Z_o(0) 1.26$
6	2898.87			$Z_o(0) 1.66$
4	2893.26			$Z_o(0) 1.00$
4	2888.20			$Z_o(0) 1.15$
4	2870.47			$Z_o(0) 1.51$
2	2839.23			$Z_o(0) 1.34$
8R	2830.29			$Z_o(0) 1.52$
4	2818.23			$Z_o(0) 1.23$
6	2803.22	$^1S_0 - (P_1)$		$g_z = 0, g_y = 1.04; Z_o = Z_o = (0) 1.04$
5R	2794.20			$Z_o(0) 1.42$
4	2793.28			$Z_o(0) 1.23$
4	2773.99			$Z_o(0) 1.45$
4	2773.28			$Z_o(0) 1.28$
4R	2771.65			$Z_o(0) 1.12$
4	2754.90			$Z_o(0) 1.33$
4	2747.59			$Z_o(0) 1.21$
4	2738.45			$Z_o(0) 1.17$
8R	2733.96			$Z_o(0) 1.20$
6R	2719.02			$Z_o(0) 1.42$
4	2713.09			$Z_o(0) 1.65$
5R	2705.88			$Z_o(0) 1.51$
6	2698.40	$^1S_0 - (P_1 \text{ or } \bar{D}_1)$		$g_z = 0, g_y = 1.49; Z_o = Z_o = (0) 1.49$
4	2694.20			$Z_o(0) 1.29$
5R	2677.13			$Z_o(0) 1.71$
4	2674.54			$Z_o(0) 1.58$
10R	2659.44			$Z_o(0.40) 1.20$
4R	2650.84			$Z_o(0) 1.55$
6R	2646.87			$Z_o(0) 1.43$
5	2639.83			$Z_o(0) 1.27$
4	2619.56			$Z_o(0) 1.29$
4	2596.00			$Z_o(0) 1.55$
4	2505.93			$Z_o(0) 1.69$

\* This value is assumed known from other calculations.

Rh<sub>45</sub> (229)

## Rh I

4	4842.40	$^1P_1 - ^1\bar{P}_1$		
	$Z_o(0.00)$	0.50		
	$Z_o(0.14)(0.40)(0.77)$	0.66 0.99 1.20 1.46 1.74 2.00		
7	4675.03	$^1F_4 - ^1D_4$		
	$Z_o$	0.94		
	$Z_o(0.14)(0.43)(0.71)(1.00)$	0.43 0.71 1.00 1.28 1.57 1.86 2.14		

Rh<sub>45</sub>.—(Continued)

Int.	$\lambda$	Terms	4	Type
Rh I.—(Continued)				
6	4569.01	$^1P_1 - ^1G_4$		
	$Z_o(0.25)$	0.00 <b>0.49</b>		
	$Z_o(0.31)(0.93)(1.55)$	0.05 <b>0.57</b> 0.67 1.29 1.91 2.53		
5	4528.74	$^1F_3 - ^1\bar{F}_4$		
	$Z_o(0.00)$			1.76
	$Z_o(0.18)(0.57)(0.95)$	0.29 0.67 1.05 1.43 1.81 <b>2.19</b>		
5	4379.93	$^1P_1 - ^1D_1$		
	$Z_o(0.71)$	1.21		
	$Z_o(0.20)(0.60)(1.00)$	0.66 1.00 <b>1.40</b> 1.80 2.20		
7	4374.81	$^1F_4 - ^1G_4$		
	$Z_o(0.00)$			1.26
	$Z_o(0.02)(0.06)(0.10)(0.14)$	1.02 1.06 1.10 1.14 1.18 1.22 1.26 <b>1.30</b>		
7	4288.72	$^1F_3 - ^1G_4$		
	$Z_o(0.00)$			1.21
	$Z_o(0.00)(0.19)(0.32)$	0.67 0.80 0.92 1.05 1.18 <b>1.30</b>		
5	4211.15	$^1F_4 - ^1F_3$		
	$Z_o(0.00)$			1.74
	$Z_o(0.01)(0.29)(0.48)(0.67)$	0.67 0.86 1.05 1.24 1.43 1.62 1.81 <b>2.00</b>		
3	4196.51	$^1P_1 - ^1G_4$		
	$Z_o(0.41)$	0.87		
	$Z_o(0.35)(1.06)(1.77)$	0.17 0.54 <b>0.88</b> 1.25 1.95 2.66		
4	4135.30	$^1F_4 - ^1\bar{F}_4$	$T_8$	
	$Z_o(0.00)$			1.15
	$Z_o(0.05)(0.14)(0.33)$	0.91 1.00 1.10 <b>1.19</b> 1.28 1.38 1.48		
6	4128.93	$^1F_3 - ^1\bar{F}_4$		
	$Z_o(0.00)$			1.59
	$Z_o(0.14)(0.43)(0.71)$	0.43 0.71 1.00 1.29 1.57 <b>1.86</b>		
4	4121.72	$^1F_3 - ^1D_1$		
	$Z_o(0.00)$			1.00
	$Z_o(0.17)(0.51)(0.86)$	0.34 0.69 <b>1.03</b> 1.37 1.71		
4	4077.59	$^1D_1' - (^1D_1')$	*	$Z_o(0.00) 1.30; Z_o(0.00) 1.20$
5	3996.16	$^1P_1 - (^1D_1')$	*	
	$Z_o(0.00)$	1.10		
	$Z_o(0.03)(0.07)$	1.30 1.35 1.40 <b>1.44</b>		
4	3995.62	$^1P_1 - ^1\bar{P}_1$		
	$Z_o(0.00)$	1.33		
	$Z_o(0.06)(0.19)$	1.41 1.54 1.66 1.79		
5	3984.41	$^1P_1 - ^1\bar{P}_1$		$Z_o(0.19) 1.52; Z_o(0.00) 1.73$
5	3975.32	$^1D_1' - (^1D_1')$	*	$Z_o(0.00) 1.19; Z_o(0.00) 1.20$
5	3958.86	$^1F_3 - ^1G_4$		
	$Z_o(0.00)$			1.07
	$Z_o(0.02)(0.05)(0.08)$	0.81 0.84 0.87 0.91 0.94 <b>0.97</b>		
5	3942.71	$^1P_1 - ^1\bar{P}_1$	†	
	$g_{x_0} = 1.56, g_{y_0} = 2.06$			
	$g_{x_0} = 1.73, g_{y_0} = 2.67$			
4	3934.23	$^1F_4 - ^1G_4$		
	$Z_o(0.44)$	1.09		
	$Z_o(0.08)(0.24)(0.55)$	0.54 0.75 0.90 <b>1.06</b> 1.22 1.38 1.54		
4	3922.18	$^1D_1 - ^1D_1$		$Z_o(0.36) 0.36 1.09; Z_o(0.40) 0.40 1.20$
4	3856.51	$^1F_4 - ^1G_4$		
	$Z_o(0.00)$			1.19
	$Z_o(0.02)(0.05)(0.08)(0.12)$	1.00 1.03 1.06 1.09 1.13 1.16 1.19 1.22		
5	3833.87	$^1F_3 - ^1D_1$		
	$Z_o(0.00)$	0.97		
	$Z_o(0.03)(0.09)$	0.77 0.83 0.89 <b>0.94</b>		
2	3828.47	$^1P_1 - ^1\bar{P}_1$	$T_8$	$Z_o(0.00) 1.48; Z_o(0.00) 1.60$
4	3822.25	$^1F_3 - ^1\bar{F}_3$		$Z_o(0.16) 0.99; Z_o(0.00) 0.86$
5	3818.20	$^1P_1 - ^1\bar{P}_1$	$T_8$	
	$Z_o(0.00)$	1.46		
	$Z_o(0.06)(0.10)$	1.41 1.54 1.66 1.79		
1	3816.46	$^1D_1' - (^1\bar{F}_1')$	*	
	$Z_o(0.00)$	1.09		
	$Z_o(0.03)(0.09)$	0.77 0.83 0.89 0.94		
4	3806.77	$^1F_3 - ^1D_1$		
	$Z_o$	0.60		1.16
	$Z_o(0.17)(0.51)(0.86)$	0.51 0.86 <b>1.20</b> 1.54 1.89		
4	3805.92	$^1D_1' - ^1D_1'$		$Z_o(0.28) 1.19; Z_o(0.00) 1.20$
4	3799.32	$^1F_4 - ^1\bar{F}_4$	$T_8$	$Z_o(0.00) 1.12; Z_o(0.00) 1.14$
4	3793.22	$^1F_4 - ^1D_1$		
	$Z_o(0.00)$			1.56
	$Z_o(0.03)(0.09)(0.14)$	1.00 1.06 1.12 1.17 1.23 1.29		
5	3788.58	$^1D_1 - ^1D_1$	†	
	$g_{x_0} = 1.15, g_{y_0} = 0.88$			
	$g_{x_0} = 1.20, g_{y_0} = 0.80$			
5	3765.08	$^1F_4 - ^1G_3$	†	
	$g_{x_0} = 1.10, g_{y_0} = 0.98$			
	$g_{x_0} = 1.14, g_{y_0} = 0.57$			



Rh<sub>45</sub>—(Continued)

Int.	$\lambda$	Terms	4	Type
Rh I.—(Continued)				
5	3748.23	$^4P_1 - ^4D_1'$		
	$Z_0$ (0.20)	0.60 0.98 1.40 1.82		
	$Z_0$ (0.18) (0.54)	0.83 1.19 1.55 1.92		
4	3744.18	$^2P_1 - (^4D_1')$	*	
	$Z_0$ (0.00)	1.26		
	$Z_0$ (0.06) (0.19)	1.39 1.26 1.14		
4	3735.28	$^2D_1 - (^2F_1')$	*	
	$Z_0$ (0.00)	1.19		
	$Z_0$ (0.03) (0.09) (0.14)	1.00 1.06 1.12 1.17 1.23 1.29		
8	3700.90	$^4F_4 - ^4G_5$		
	$Z_0$ (0.00)	1.15		
	$Z_0$ (0.03) (0.10) (0.17) (0.23)	0.94 1.00 1.07 1.14 1.20 1.27 1.33 1.40		
5	3698.61	$^2G_5 - (^2F_1')$	*	
	$Z_0$ (0.00)	1.02		
	$Z_0$ (0.02) (0.05) (0.08) (0.11)	1.00 1.03 1.06 1.09 1.13 1.16 1.19 1.22		
3	3698.27	$^4P_1 - ^4D_1'$		
	$Z_0$ (0.77)	0.37 1.91		
	$Z_0$ (0.73)	0.47 1.93		
10	3692.36	$^4F_5 - ^4D_4$		
	$Z_0$ (0.00)	1.27		
	$Z_0$ (0.05) (0.14) (0.24) (0.33)	1.00 1.10 1.19 1.28 1.38 1.48 1.57 1.67		
4	3690.72	$^2D_1 - ^4D_1$	$T_s$	$Z_0$ (0.00) 1.06; $Z_0$ (0.00) 1.20
6	3681.06	$^2P_1 - (^2D_1')$	*	
	$Z_0$ (0.00)	1.40		
	$Z_0$ (0.07) (0.20)	1.00 1.14 1.27 1.40		
5	3674.77	$^4P_1 - ^2P_1$		$Z_0$ (0.63) 0.63 1.92 $Z_0$ (0.67) 0.67 1.99 $Z_0$ (0.00) 1.26; $Z_0$ (0.00) 1.33
4	3666.92	$^2P_1 - ^2P_1$	$T_s$	
7	3666.23	$^4F_3 - ^4F_4$	$T_s$	
	$Z_0$ (0.00)	1.18		
	$Z_0$ (0.10) (0.31) (0.52) 0.71 0.92 1.13 1.34 1.55 1.76			
3	3661.88	$^2G_4 - (^2F_1')$	*	
	$Z_0$ (0.00)	0.69		
	$Z_0$ (0.06) (0.17) (0.28)	0.62 0.73 0.85 0.96 1.07 1.18		
8	3658.00	$^4F_4 - ^4D_1$		
	$Z_0$ (0.00)	1.19		
	$Z_0$ (0.07) (0.20) (0.33)	0.90 1.04 1.17 1.31 1.44 1.57		
6	3639.53	$^4P_1 - ^4D_1'$		$Z_0 = Z_0 = (1.33) 1.33$
7	3626.61	$^4P_1 - ^4D_1'$		
	$Z_0$ (0.00)	1.01		
	$Z_0$ (0.09) (0.26) (0.43)	1.00 1.17 1.34 1.52 1.69 1.86		
5	3620.47	$^2F_3 - ^4P_1$		
	$Z_0$ (0.20)	0.20 0.72		
	$Z_0$ (0.37) (1.11)	0.25 0.49 1.23 1.97		
4	3614.78	$^2G_4 - (^2F_1')$	*	
	$Z_0$ (0.00)	0.81		
	$Z_0$ (0.02) (0.05) (0.08) 0.81 0.84 0.87 0.91 0.94 0.97			
5	3612.47	$^4P_1 - ^4D_1$		$Z_0$ (0.23) 0.23 0.69 $Z_0$ (0.20) 0.20 0.60
5	3605.88	$^4P_1 - ^4D_1'$	†	
	$\sigma_{20} = 1.60, \sigma_{30} = 1.17$			
	$\sigma_{20} = 1.73, \sigma_{30} = 1.20$			
6	3597.15	$^2D_1 - ^4G_4$		
	$Z_0$ (0.00)	0.72		
	$Z_0$ (0.11) (0.33) (0.55)	0.43 0.65 0.87 1.09		
4	3596.19	$^4F_3 - ^4D_1$		
	$Z_0$ (0.00)	1.02		
	$Z_0$ (0.09) (0.26)	0.77 0.94 1.11 1.29		
4	3583.09	$^4F_4 - ^4F_5$		
	$Z_0$ (0.00)	1.36		
	$Z_0$ (0.05) (0.14) (0.24) (0.33)	1.00 1.10 1.19 1.29 1.38 1.48 1.57 1.67		
4	3570.18	$^4F_2 - ^4F_3$	†	
	$\sigma_{20} = 0.84, \sigma_{30} = 0.47$			
	$\sigma_{20} = 1.03, \sigma_{30} = 0.40$			
5	3543.97	$^2D_1 - ^2D_1$		$Z_0$ (0.24) 0.85; $Z_0$ (0.00) 0.80 $Z_0$ (0.64) 0.64 1.95; $Z_0$ (0.67) 0.67 1.99
4	3541.92	$^4P_1 - ^2P_1$		
	$Z_0$ (0.00)	1.02		
	$Z_0$ (0.09) (0.26)	0.77 0.94 1.11 1.29		
7	3528.03	$^4F_4 - ^4F_4$		$Z_0$ (0.28) 1.23; $Z_0$ (0.00) 1.24
4	3513.11	$^2P_1 - ^2P_1$		$Z_0$ (0.33) 1.73 1.03 $Z_0$ (0.33) 1.67 1.00
4	3507.32	$^4F_3 - ^4G_4$		
	$Z_0$ (0.00)	0.91		
	$Z_0$ (0.02) (0.07) (0.11)	0.87 0.92 0.96 1.01 1.05 1.10		
8	3502.54	$^4F_5 - ^4G_5$		
	$Z_0$ (0.08) (0.24) (0.40) (0.57)	(0.73) 0.61 0.77 0.93 1.04 1.26 1.42 1.58		
	$Z_0$ (0.00)	1.74 1.90		
7	3498.74	$^4P_2 - ^2D_1$	†	
	$\sigma_{20} = 0.52, \sigma_{30} = 1.03$			
	$\sigma_{20} = 0.40, \sigma_{30} = 1.20$			

Rh<sub>45</sub>—(Continued)

Int.	$\lambda$	Terms	4	Type
Rh I.—(Continued)				
4	3484.04	$^2D_1 - ^2F_4$	$T_s$	
	$Z_0$ (0.00)	1.12		
	$Z_0$ (0.03) (0.08) (0.14)	1.00 1.06 1.12 1.17 1.23 1.29		
4	3478.91	$^2D_1 - ^2D_1$		$Z_0$ (0.30) 1.07; $Z_0$ (0.00) 1.20
5	3474.79	$^4F_3 - ^4G_3$	†	
	$\sigma_{20} = 0.94, \sigma_{30} = 0.48$			
	$\sigma_{20} = 0.57, \sigma_{30} = 0.40$			
4	3470.67	$^4F_3 - ^4F_3$		$Z_0$ (0.14) 0.53; $Z_0$ (0.00) 0.40
4	3462.04	$^4F_3 - ^4F_3$	†	
	$\sigma_{20} = 1.08, \sigma_{30} = 0.80$			
	$\sigma_{20} = 1.03, \sigma_{30} = 1.03$			
	3434.90	$^4F_3 - ^4G_3$		
	$Z_0$ (0.00)	1.18		
	$Z_0$ (0.03) (0.09) (0.15) (0.21) (0.27)	1.00 1.06 1.12 1.18 1.24 1.30 1.36		
	$Z_0$ (0.00)	1.42 1.49 1.55		
7	3399.68	$^4F_3 - ^2F_4$	$T_s$	
	$Z_0$ (0.00)	1.13		
	$Z_0$ (0.06) (0.17) (0.29)	0.86 0.97 1.09 1.20 1.32 1.43		
8	3396.82	$^4F_3 - ^4F_3$		$Z_0$ (0.28) 1.34; $Z_0$ (0.00) 1.33
	3372.84	$^4F_3 - ^4G_3$		
	$Z_0$ (0.42)	1.03		
	$Z_0$ (0.23) (0.69) (1.14)	0.11 0.34 0.80 1.26 1.71		
6	3368.38	$^4F_3 - ^4F_3$	†	
	$\sigma_{20} = 1.04, \sigma_{30} = 0.48$			
	$\sigma_{20} = 1.03, \sigma_{30} = 0.40$			
6	3323.09	$^4F_3 - ^4G_3$		
	$Z_0$ (0.00)	1.07		
	$Z_0$ (0.06) (0.19) (0.32) (0.44)	0.67 0.79 0.92 1.05 1.18 1.30 1.42 1.55		
4	3283.57	$^4F_3 - ^4G_4$		
	$Z_0$ (0.00)	0.67		
	$Z_0$ (0.06) (0.17) (0.28)	0.62 0.73 0.85 0.96 1.07 1.18		
4	3280.54	$^4F_4 - ^2F_4$		
	$Z_0$ (0.00)	0.39		
	$Z_0$ (0.05) (0.14) (0.24)	(0.33) 0.91 1.00 1.10 1.19 1.28 1.38 1.48		
8	3271.61	$^2D_1 - ^2D_1$		
	$Z_0$ (0.00)	1.38		
	$Z_0$ (0.20) (0.60) 0.60 1.00 1.40 1.80			
8	3263.14	$^2D_1 - ^2F_3$		
	$Z_0$ (0.28)	1.05		
	$Z_0$ (0.17) (0.51) (0.86)	0.34 0.69 1.03 1.37 1.71		
6	3191.18	$^2D_1 - ^4D_1'$	†	
	$\sigma_{20} = 1.24, \sigma_{30} = 0.81$			
	$\sigma_{20} = 1.37, \sigma_{30} = 0.80$			

\* Second term—(D), (F)—not positively established.

† If type deviates from the theoretical one, the author gives only  $\sigma$ -values.Sc<sub>21</sub> (86); Int. and  $\lambda$  (64); cf. (147); spectral structure (38, 40, 80, 86, 146, 149)

Sc I				
10	4047.81	$^2D_1 - ^2D_1'$		[(1) (3) 5 7 9]/5
	$Z_0$ 1.77 1.39 0.98 (0.59) (0.19) (0.19) (0.56) 0.96 1.33 1.71			
	$Z_0$ 1.80 1.40 1.00 (0.60) (0.20) (0.20) (0.60) 1.00 1.40 1.80			
30	4023.68	$^2D_1 - ^2D_1'$	s	[(0) 6]/5
	$Z_0$ 1.21 (0) 1.21; $Z_0$ 1.20 (0) 1.20			
20	4020.40	$^2D_1 - ^2D_1'$	s	[(0) 4]/5
	$Z_0$ 0.80 (0) 0.81; $Z_0$ 0.80 (0) 0.80			
15	3996.61	$^2D_1 - ^2D_1'$		[(1) (3) 5 7 9]/5
	$Z_0$ 1.79 1.40 1.00 (0.62) (0.19) (0.19) (0.56) 0.98 1.40 1.76			
	$Z_0$ 1.80 1.40 1.00 (0.60) (0.20) (0.20) (0.60) 1.00 1.40 1.80			
30	3911.88	$^2D_1 - ^2F_4$	s <sub>1</sub> *	[(1) (3) (5) 25 37 39 41 43 45]/35
	$Z_0$ 1.07 (0) 1.06; $Z_0$ 1.00 (0) 1.00			
30	3907.54	$^2D_1 - ^2F_3$	s—*	[(1) (3) 27 29 31 33]/35
	$Z_0$ 0.90 (0) 0.91; $Z_0$ 0.94 (0) 0.94			
5	3269.84	$^2D_1 - ^2P_1$	W, d	[(1) 11 13]/15
	$Z_0$ 0.87 (0) 0.76			
	$Z_0$ 0.86 0.74 (0.07) (0.07) 0.74 0.86			
Sc II				
20	4415.55	$^2F_3' - ^2F_3$	s	[(0) 2]/3
	$Z_0$ 0.69 (0) 0.67; $Z_0$ 0.67 (0) 0.67			
20	4400.39	$^2F_3' - ^2F_3$	s	[(0) 13]/12
	$Z_0$ 1.09 (0) 1.10; $Z_0$ 1.08 (0) 1.08			
30	4374.51	$^2F_3' - ^2F_3$	s	[(0) 5]/4
	$Z_0$ 1.28 (0) 1.37; $Z_0$ 1.25 (0) 1.25			
20	4325.00	$^2F_3' - ^2D_1'$	s <sub>2</sub> *	[(0) (1) 3 4 5]/6
	$Z_0$ 0.79 (0) 0.79; $Z_0$ 0.83 (0) 0.83			
20	4320.75	$^2F_3' - ^2D_1'$	s <sub>1</sub> *	[(0) (1) (2) (3) 11 12 13 14 15 16]/12
	$Z_0$ 0.98 (0) 0.96; $Z_0$ 0.92 (0) 0.92			



Sc<sub>II</sub>.—(Continued)

Int.	$\lambda$	Terms	4	Type
Sc II.—(Continued)				
30	4314.09	$^3F'_4 - ^3D'_2$	$s_1^*$	[(0) (1) (2) (3) 12 13 14 15 16 17 18]/12
		$Z_0$ 1.09 (0) 1.10; $Z_0$ 1.00 (0) 1.00		
50	4246.88		$s_1$	$Z_0$ 0.99 (0) 0.98
20	3651.99	$^3D_2 - ^3F_2$	$\dagger\dagger$	[1 (3) 4 (6) 7 10]/6
		$Z_0$ 1.58 1.00 0.57		0.57 1.04 1.67
		$Z_0$ 1.67 1.17 (1.00) 0.67 (0.50) 0.16 0.16 (0.50) 0.67 (1.00) 1.17 1.67		
15	3645.48	$^3D_2 - ^3F_2$	$\perp D^*$	[(3) (6) (9) 7 10 13 16 19 22]/12
		$Z_0$ (?) 0.69 0.68 (?)		
		$Z_0$ 1.21 (0.75) (0.75) 1.21		
50	3642.96	$^3D_1 - ^3F_2$	$B, s_1^*$	[(0) (1) 3 4 5]/6
		$Z_0$ 0.78 (0) 0.77; $Z_0$ 0.83 (0) 0.83		
100	3630.75	$^3D_1 - ^3F_2$	$s_1^*\dagger$	[(0) (1) (2) (3) 11 12 13 14 15 16]/12
		$Z_0$ 1.03 (0) 1.03; $Z_0$ 0.92 (0) 0.92		
100	3613.83	$^3D_1 - ^3F_2$	$s_1^*$	[(0) (1) (2) (3) 12 13 14 15 16 17 18]/12
		$Z_0$ 1.11 (0) 1.12; $Z_0$ 1.00 (0) 1.00		
10	3590.52	$^3D_1 - ^3D'_2$	$s_1^*\dagger\dagger$	[(0) (1) (2) 6 7 8 9 10]/6
		$Z_0$ 1.42 (0) 1.51; $Z_0$ 1.67 (0) 1.67		
10	3589.67	$^3D_1 - ^3D'_2$	$\dagger\dagger$	[(0) 3 4 7 11]/6
		$Z_0$ 1.83 1.17 0.65 (0) 0.61 1.18 1.76		
		$Z_0$ 1.83 1.17 (0.67) 0.50 (0) 0.50 (0.67) 1.17 1.83		
20	3580.98	$^3D_1 - ^3D'_2$	$s_1$	[(0) 1]/2
		$Z_0$ 0.51 (0) 0.51; $Z_0$ 0.50 (0) 0.50		
30	3576.37	$^3D_1 - ^3D'_2$	$s_1$	[(0) 7]/6
		$Z_0$ 1.14 (0) 1.19; $Z_0$ 1.17 (0) 1.17		
50	3572.57	$^3D_1 - ^3D'_2$	$s_1$	[(0) 4]/3
		$Z_0$ 1.31 (0) 1.34; $Z_0$ 1.33 (0) 1.33		
20	3567.72	$^3D_1 - ^3D'_2$	$\dagger$	[(0) 3 (4) 7 11]/6
		$Z_0$ 1.83 1.16 0.64 (0) 0.64 1.15 1.83		
		$Z_0$ 1.83 1.17 (0.67) 0.50 (0) 0.50 (0.67) 1.17 1.83		
20	3558.56	$^3D_1 - ^3D'_2$	$s_1^*$	[(0) (1) (2) 6 7 8 9 10]/6
		$Z_0$ 1.63 (0) 1.64; $Z_0$ 1.67 (0) 1.67		
10	3535.74			$Z_0$ 1.98 (0) 1.02
10	3372.16	$^3D_1 - ^3P_1$	$s_1^*$	[(0) (1) (2) 6 7 8 9 10]/6
		$Z_0$ 1.16 (0) 1.13; $Z_0$ 1.00 (0) 1.00		
8	3359.69	$^3D_1 - ^3P_1$	$\perp D^*$	[(2) (4) 5 7 9 11]/6
		$Z_0$ (?) 0.66 0.66 (?)		
		$Z_0$ 1.83 (0.67) (0.67) 1.83		
20	3353.74		$d$	$Z_0$ 1.00 (0) 1.00

\* Only strongest components of  $Z_0$  are given decimally.

† Asymmetric; inner components too weak.

‡ Measured on plate with two states of polarization.

§ Splitting-up is too great, cf.  $\lambda = 4320.75$ .|| Splitting-up is too simple, cf.  $\lambda = 3558.56$ .¶ The 1.42 of  $\lambda = 3590.52$  coincides with the 1.76 of  $\lambda = 3589.67$ Sn<sub>II</sub> (92); cf. (16); spectral structure (16, 92, 141, 175, 203, 264)

Sn I; Int. (94); $\lambda$ (16); Terms (92)				
3	5631.69	$3s^2P'_1 - 2p^1S'_0$		$Z_0 = Z_0 = (0) 1.38$
15	4524.74	$3s^2P'_1 - 2p^1S'_0$		$Z_0 = Z_0 = (0) 1.115$
30	3801.031	$3s^2P'_1 - 2p^1D'_1$		$Z_0 = Z_0 = (0) (0.34) 0.715$ 1.06 1.40
5	3655.78	$3d^3D_1 - 2p^1S'_0$		$Z_0 = Z_0 = (0) 0.64$
20	3330.60	$3s^2P'_1 - 2p^1D'_1$		$Z_0$ (0.44) (0.89) 0.59 1.07 1.51 1.96 $Z_0$ (0.45) (0.90) 0.60 1.06 1.51 1.96
100	3282.33	$3s^2P'_1 - 2p^1D'_1$		$Z_0$ (0) 1.01 $Z_0$ (0) (0.07) 0.97 1.04 1.12
3	3218.690	$4s^2P'_1 - 2p^1S'_0$	*	$Z_0 = Z_0 = (0) 1.32$
100	3175.039	$3s^2P'_1 - 2p^1P_1$		$Z_0$ (0) 1.50 $Z_0$ (0) (0.07) 1.38 1.45 1.53
5	3141.81	$(?) 3d^3P_1 - 2p^1S'_0$		$Z_0 = Z_0 = (0) 1.22$
6R	3034.16	$3s^2P'_1 - 2p^1P_1$		$Z_0 = Z_0 = (0) 1.51$
8	3032.78	$3d^3P_1 - 2p^1S'_0$		$Z_0 = Z_0 = (0) 1.055$
50	3009.138	$3s^2P'_1 - 2p^1P_1$	†	$Z_0$ (0.12) 1.44 $Z_0$ (0.12) 1.38 1.50 $Z_0 = Z_0 = (0) 0.845$ $Z_0 = Z_0 = (0) 1.38$
10	2913.542	$4d^3D_1 - 2p^1S'_0$		
20	2863.320	$3s^2P'_1 - 2p^1P_1$		
10	2850.61	$3d^3D_1 - 2p^1D'_1$		$Z_0$ (0.30) 0.94 $Z_0$ (0.19) (0.38) 0.67 0.86 1.05 1.24
30	2839.99	$3s^2P'_1 - 2p^1P_1$		$Z_0$ (0) 1.50 $Z_0$ (0.05) (0.10) 1.42 1.47 1.52 1.57

Sn<sub>II</sub>.—(Continued)

Int.	$\lambda$	Terms	4	Type
Sn I.—(Continued)				
4	2813.58	$3d^3F'_2 - 2p^1D_2$		
		$Z_0$ (0) 1.09		
		$Z_0$ (0) (0.08) (0.16) 1.05 1.13 1.21		
3	2785.027	$3d^3D_1 - 2p^1D'_2$		$Z_0$ (0) 1.39
4	2779.814	$3d^3F'_2 - 2p^1D'_2$		
		$Z_0$ (0) 1.30		
		$Z_0$ (0) (0.12) (0.23) 0.935 1.05 1.17 1.28 1.39		
10	2706.50	$3s^2P'_1 - 2p^1P_1$		$Z_0 = Z_0 = (0) 1.51$
3	2661.25	$3s^2P'_1 - 2p^1P_1$		$Z_0$ (0.38) 1.15 1.50 $Z_0$ (0.38) 1.14 1.51
5	2571.60	$3d^3D_2 - 2p^1D'_2$	†	
		$Z_0$ 1.46		
		$Z_0$ (0) (0.19) (0.38) 0.6 1.05 1.24 1.43 1.62		
1	2456	$3d^3F'_2 - 2p^1P_1$		$Z_0$ 1.01 (0) 1.24 $Z_0$ 1.125 (0) 1.125
6	2421.70	$3d^3F'_2 - 2p^1D'_2$		
		$Z_0$ (0) 1.00		
		$Z_0$ (0) (0.025) (0.050) 0.975 1.000 1.025 1.050 1.075		
4	2334.799	$3d^3D_1 - 2p^1P_1$		Not resolved, but $j_1 = j_2$
Sn II; Int. and $\lambda$ (175); Terms (92)				
20	6452.79	$6^3S_1 - 6^3P_2$		$Z_0$ (0.36) 1.01 1.66; $Z_0$ (0.33) 1.00 1.67 $Z_0$ (0) 1.07
25	5799.35	$5^3D_{21} - 4^3F_{41}$		
8	5598.15	$6^3P_2 - 6^3D_2$		
		$Z_0$ (0.80) 0.55 1.06 1.60		
		$Z_0$ (0.27) (0.80) 0.53 1.07 1.60		
30	5589.44	$5^3D_2 - 4^3F_2$		$Z_0$ (0) 0.90
30	5562.92	$6^3P_2 - 6^3D_2$		
		$Z_0$ (0) 1.04		
		$Z_0$ (0.07) (0.20) 1.00 1.13 1.27		
30	5333.23	$6^3P_1 - 6^3D_2$		$Z_0$ (0) 0.835 $Z_0$ (0.07) 0.73 0.87
30	3352.42	$p^3D_1 - 4^3F_{41}$	cf. $\lambda = 5799$	$Z_0$ (0) 1.06
30	3283.54	$p^3D_1 - 4^3F_2$	cf. $\lambda = 5589$	$Z_0$ (0) 0.91
Sn III; Int. (94)				
3	5369.5	$6^3P_0 - 5^3D_1$		$Z_0$ (0) 0.48; $Z_0$ (0) 0.50
4	5349.37	$6^3P_1 - 5^3D_2$		
		$Z_0$ (0) 0.96		
		$Z_0$ (0) (0.33) 0.83 1.17 1.50		
1	5291	$6^3P_1 - 5^3D_1$		$Z_0$ (0.95) 0.47 1.41; $Z_0$ (1.00) 0.50 1.50 $Z_0$ (0) 1.04; $Z_0$ (0) 1.00
5	5224.92	$5^3D_2 - 6^3P_1$	D	
7	5100.56	$6^3P_2 - 5^3D_2$		
		$Z_0$ (0) 1.10		
		$Z_0$ (0) (0.16) (0.33) 1.00 1.17 1.33 1.50 1.67		
1	5020.7	$6^3P_2 - 5^3D_2$		
		$Z_0$ (0.67) 1.29		
		$Z_0$ (0.33) (0.67) 0.83 1.17 1.50 1.83		
6	4924.12	$6^3S_1 - 6^3P_0$		$Z_0$ (0) (1.97); $Z_0$ (0) 2.00
6	4858.12	$6^3S_1 - 6^3P_1$		$Z_0$ (0.55) 1.49 2.02; $Z_0$ (0.50) 1.50 2.00
0	4715.82	$5^3D_2 - 6^3P_1$		
		$Z_0$ (0) 1.20		
		$Z_0$ (0) (0.16) 1.00 1.16 1.33		
20	4585.62	$6^3S_1 - 6^3P_2$		
		$Z_0$ (0) (0.50) 1.03 1.52		
		$Z_0$ (0) (0.50) 1.00 1.50 2.00		
5	4330.13	$6^3S_1 - 6^3P_1$		$Z_0$ (0.93) 0.99 2.00; $Z_0$ (1.00) 1.00 2.00
		$Z_0$ (0) 1.75		
		$Z_0$ (0) (0.50) 1.00 1.50 2.00		

\* Very asymmetric. † Outside components are resolved, but not measurable.

‡ Shaded symmetrically. § Obscured by lines of band.

V<sub>22</sub> (24); Int. (119);  $\lambda$  (64, 112); Terms (24, 42, 80, 127, 144)

V I				
7	6266.28	$^3D'_2 - ^3F'_2$		
		$Z_0$ (0.25) (0.67) 1.40 1.91 2.38		
		$Z_0$ (0.30) (0.89) 0.77 1.36 1.95 2.54		
5	6261.18	$^3D'_2 - ^3F'_1$		$Z_0$ 0.78 (1.12) 3.05; $Z_0$ 0.60 (1.37) 3.13 $Z_0$ 1.47 (1.94); $Z_0$ 1.33 (2.00)
2	6245.14	$^3D'_1 - ^3F'_1$		
6	6240.09	$^3D'_1 - ^3F'_1$		
		$Z_0$ 0.84 (1.05) 1.50 2.21		
		$Z_0$ (0.40) 0.67 (1.30) 1.47 2.27		
12	6233.10	$^3D'_1 - ^3F'_1$		
		$Z_0$ 0.74 1.42		
		$Z_0$ (0.17) (0.51) 0.80 (0.86) 1.14 1.49 1.83 2.17		



V<sub>23</sub>—(Continued)

Int.	λ	Terms	4	Type
V I.—(Continued)				
1	6221.18	$^3P'_4 - ^3D'_0$		
	Z <sub>0</sub> 0.54			
	Z <sub>0</sub> 0.17 (0.52) 0.86 (1.54) 1.88			
15	6213.83	$^3D'_2 - ^3F'_2$		
	Z <sub>0</sub> 0.45			1.48
	Z <sub>0</sub> (0.06) (0.18) (0.30) (0.42) (0.54) 1.01 1.13 1.25 1.37 1.49 1.62			
	1.74 1.86 1.98			
1	6190.49	$^3P'_2 - ^3D'_2$		
	Z <sub>0</sub> 1.16			
	Z <sub>0</sub> (0.26) 0.60 (0.77) 1.12 (1.29) 1.63 2.14 2.66			
3	6189.34	$^3D'_2 - ^3F'_4$		
	Z <sub>0</sub> (?) 1.00			
	Z <sub>0</sub> (0.13) (0.39) (0.65) 0.75 1.01 1.27 1.62 1.79 2.05			
15	6150.11	$^3D'_2 - ^3F'_0$		
	Z <sub>0</sub> (?) 1.14			
	Z <sub>0</sub> (0.05) (0.15) (0.25) (0.35) (0.45) 1.00 1.10 1.20 1.30 1.40 1.50 1.60			
	1.70 1.80 1.90			
2	6017.94	$^3P'_2 - ^3D'_2$		
	Z <sub>0</sub> 0.74 0			
	Z <sub>0</sub> 0.27 (0.80) 0.93 1.46 2.00			
1	6008.68	$^3P'_1 - ^3D'_1$		
2	6002.30	$^3P'_3 - ^3D'_4$		
	Z <sub>0</sub> (?) 1.16			Z <sub>0</sub> 1.26 (1.40); Z <sub>0</sub> 1.33 (1.33)
	Z <sub>0</sub> (0.09) (0.26) (0.43) 1.00 1.17 1.34 1.52 1.69 1.86 1.94			
3	5980.81	$^3P'_2 - ^3D'_2$		
	Z <sub>0</sub> ? 1.02			
	Z <sub>0</sub> (0.18) 0.54 0.83 1.19 1.55 1.92			
1	5610.20	$^3F'_4 - ^3F'_4$		
	Z <sub>0</sub> (0)			1.26
	Z <sub>0</sub> (0.03) (0.09) (0.16) (0.22) 1.11 1.18 1.24 1.30 1.36 1.43 1.49 1.56			
1	5593.02	$^3F'_4 - ^3D'_2$		
	Z <sub>0</sub> (?) 1.49			
	Z <sub>0</sub> 0.19 (0.21) 0.82 (0.66) 1.03 (1.05) 1.45 1.86 2.29			
1	5588.47	$^3D'_4 - ^3D'_4$		
	Z <sub>0</sub> (0.48) 1.55			
	Z <sub>0</sub> (0.08) (0.24) (0.40) (0.56) 1.03 1.19 1.35 1.51 1.67 1.83 1.99			
1+	5578.33	$^3D'_2 - ^3D'_1$		
1	5573.98	$^3F'_4 - ^3F'_2$		
	Z <sub>0</sub> (0) 1.10			Z <sub>0</sub> 0 (1.06); Z <sub>0</sub> 0.13 (1.06) 2 27
	Z <sub>0</sub> (0.04) (0.11) (0.19) 1.04 1.12 1.20 1.28 1.35 1.43			
1	5565.93	$^3D'_2 - ^3D'_2$		
	Z <sub>0</sub> (?) 1.59			
	Z <sub>0</sub> (0.33) 0.87 (1.00) 1.54 2.20			
4	5547.04	$^3D'_4 - ^3D'_2$		
	Z <sub>0</sub> (0)			1.77
	Z <sub>0</sub> (0.06) (0.19) (0.32) (0.44) 1.11 1.24 1.36 1.49 1.62 1.75 1.87 2.00			
2	5545.91	$^3D'_2 - ^3D'_4$		
	Z <sub>0</sub> (0) 1.92			
	Z <sub>0</sub> (0.11) (0.32) (0.54) 1.05 1.26 1.49 1.70 1.92 2.13			
1	5542.69	$^3F'_2 - ^3F'_2$		
	Z <sub>0</sub> (0) 0.96			
	Z <sub>0</sub> (0.02) (0.06) 0.97 1.01 1.05 1.08			
1	5517.18	$^3F'_2 - ^3P'_1$		
1	5515.05	$^3F'_2 - ^3F'_2$		
	Z <sub>0</sub> (?) 0.13			Z <sub>0</sub> (0.42) 0.79; Z <sub>0</sub> (0.53) 0.93
	Z <sub>0</sub> 0.06 (0.18) (0.30) (0.42) (0.55) 0.91 1.03 1.15			1.74
	1.27 1.40 1.52 1.64 1.76 1.88 2.00			
4	4932.03	$^3P'_2 - ^3P'_2$		
	Z <sub>0</sub> (0) 1.52			
	Z <sub>0</sub> (0.07) (0.20) 1.40 1.53 1.67 1.80			
10	4925.66	$^3P'_2 - ^3P'_2$		
2	4886.82	$^3P'_2 - ^3P'_2$		
8	4880.56	$^3P'_2 - ^3P'_2$		
	Z <sub>0</sub> (0) 0.90 1.65			
	Z <sub>0</sub> (0.07) (0.20) 1.40 1.53 1.67 1.80			
12	4412.16	$^3D'_1 - ^3P'_1$		
5	4392.10	$^3D'_1 - ^3P'_1$		
	Z <sub>0</sub> 1.98 1.76			Z <sub>0</sub> (0.37) 2.94; Z <sub>0</sub> (0.33) 3.00
	Z <sub>0</sub> (0.07) (0.20) 1.67 1.80 1.93			
5	4363.53	$^3D'_1 - ^3P'_1$		
5	4124.09	$^3P'_2 - ^3D'_2$	*	
	Z <sub>0</sub> (0.55) 1.11			Z <sub>0</sub> = Z <sub>0</sub> = (0) 1.60
	Z <sub>0</sub> (0.20) (0.60) 0.80 (1.00) 1.00 1.40 1.80 2.20			
4	4107.48	$^3P'_2 - ^3D'_2$	*	
	Z <sub>0</sub> 0.39 (0.43) 1.26 (1.35)			
	Z <sub>0</sub> 0.33 (0.47) 1.26 (1.40) 2.20			
3	4092.40	$^3P'_1 - ^3D'_2$	*	
	Z <sub>0</sub> (0.17) (0.55) 0.76 1.14 1.50			
	Z <sub>0</sub> (0.27) (0.40) 0.80 0.93 1.47 2.00			

V<sub>23</sub>—(Continued)

Int.	λ	Terms	4	Type
V I.—(Continued)				
2	4070.78	$^3F'_4 - ^3F'_4$		
	Z <sub>0</sub> 0.38			1.32
	Z <sub>0</sub> (0.05) (0.15) (0.25) (0.35) (0.45) 0.97 1.07 1.17 1.27 1.37 1.48			
	1.58 1.68 1.78			
2	4068.00	$^3F'_2 - ^3F'_2$		
	Z <sub>0</sub> (0) 1.03			
	Z <sub>0</sub> (0.04) (0.11) (0.19) 1.04 1.12 1.20 1.28 1.35 1.43			
1	4052.47	$^3F'_4 - ^3F'_4$		
	Z <sub>0</sub> 0.53 (?)			
	Z <sub>0</sub> (0.08) (0.24) (0.40) (0.56) 0.84 1.00 1.16 1.32 1.48 1.74 1.90			
2	4048.61	$^3F'_2 - ^3F'_2$		
	Z <sub>0</sub> (0) 0.98			
	Z <sub>0</sub> (0.02) (0.06) (0.99) 1.03 1.08 1.12			
1	4032.85	$^3F'_2 - ^3P'_1$		
	Z <sub>0</sub> (?) 0.90			
	Z <sub>0</sub> 0.13 (0.53) 0.94			
12	3943.65	$^3D'_4 - ^3D'_2$		
	Z <sub>0</sub> (0) 1.44			
	Z <sub>0</sub> (0.11) (0.34) (0.57) 0.86 1.09 1.31 1.54 1.77 2.00			
5	3936.32	$^3D'_2 - ^3D'_2$		
	Z <sub>0</sub> (0.29) 0.51 (0.86) 1.09 1.66 2.23			
	Z <sub>0</sub> (0.26) 0.48 (0.77) 1.09 1.60 2.08			
12	3922.46	$^3D'_2 - ^3D'_2$		
	Z <sub>0</sub> (0) 1.33			
	Z <sub>0</sub> (0.09) (0.26) (0.43) 0.94 1.11 1.29 1.46 1.62			
5	3920.49	$^3D'_2 - ^3D'_2$		
	Z <sub>0</sub> 0.53 0.60 0.98 1.40			
	Z <sub>0</sub> (0.20) (0.60) 0.60 1.00 1.40			
5	3910.78	$^3D'_1 - ^3D'_2$		
	Z <sub>0</sub> (0.39) 0.41 1.20; Z <sub>0</sub> (0.40) 0.40 1.20			
6	3906.75	$^3D'_1 - ^3D'_2$		
6	3397.50	$^3P'_1 - ^3P'_1$		
	Z <sub>0</sub> (0) 1.48			
	Z <sub>0</sub> (0.07) (0.20) 1.40 1.53 1.67 1.80			
15	3377.61	$^3P'_1 - ^3P'_1$		
10	3377.37	$^3P'_1 - ^3P'_1$		
	Z <sub>0</sub> (0) 1.49; Z <sub>0</sub> (0) 1.60			
	Z <sub>0</sub> (0.45) 1.21 2.10; Z <sub>0</sub> (0.47) 1.27 2.20			
8	3376.06	$^3P'_2 - ^3P'_2$		
4	3366.88	$^3P'_1 - ^3P'_1$		
10	3365.57	$^3P'_1 - ^3P'_2$		
	Z <sub>0</sub> (0) 1.59; Z <sub>0</sub> (0) 1.73			
	Z <sub>0</sub> (0) 2.54; Z <sub>0</sub> (0) 2.66			
	Z <sub>0</sub> (0.46) 1.07 2.05; Z <sub>0</sub> (0.47) 1.27 2.20			
10	3356.36	$^3P'_2 - ^3P'_1$		
	Z <sub>0</sub> (0) 1.38			
	Z <sub>0</sub> (0.07) (0.20) 1.40 1.53 1.67 1.80			
5	3259.53	$^3D'_1 - ^3P'_1$		
	Z <sub>0</sub> (0) 1.02			
	Z <sub>0</sub> (0.18) (0.54) 0.83 1.19 1.55 1.92			
9	3255.65	$^3D'_1 - ^3P'_1$		
	Z <sub>0</sub> (0) (?) 1.15			
	Z <sub>0</sub> (0.09) (0.26) (0.43) 1.00 1.17 1.34 1.52 1.69 1.86			
3	3243.29	$^3D'_1 - ^3P'_1$		
4	3241.17	$^3D'_1 - ^3P'_1$		
	Z <sub>0</sub> (1.30) 1.28; Z <sub>0</sub> (1.33) 1.33			
	Z <sub>0</sub> (0.49) 1.43			
	Z <sub>0</sub> (0.11) (0.34) (0.57) 1.03 1.26 1.49 1.72 1.95			

\* The (4) and the (2) are uncertain.

W<sub>74</sub> (28); Int. (29); λ (29, 112); spectral structure (128)

Int.	λ	Z <sub>0</sub>
W I		
6	5514.712	(0.000) (1.041) 0.459 1.501 2.542
6	5224.680	(0.000) (0.435) (0.870) 0.734 1.069 1.504 1.939 2.374
8	5053.300	(0.968) 1.433 2.401
6	4843.829	(0.413) (0.826) 1.056 1.469 1.883 2.296
4	4757.565	(0.000) 2.046
6	4680.539	(0.280) (0.560) (0.840) 0.926 1.206 1.486 1.766 2.046
		2.327
6	4659.886	(0.000) 2.532
8	4570.64	(0.000) (0.487) (0.974) 0.521 1.008 1.495 1.982 2.469
6	4484.197	(0.000) (0.417) 1.527 1.944 2.361
3	4460.523	(0.000) (0.534) 0.570 1.104 1.638
3	4378.501	(0.000) (0.360) (0.720) 2.090 2.450 2.810 3.170 3.530
6	4302.123	(0.241) (0.482) (0.723) 1.318 1.559 1.799 2.041 2.282
		2.523
3	4274.554	(1.344) 1.612 2.956
5	4269.399	(0.000) (1.184) 2.367
6	4074.374	(0.253) (0.505) (0.758) 1.334 1.586 1.839 2.092 2.344
		2.597
2	4071.939	(0.000) (0.371) 1.666 2.036 2.407
4	4070.618	(0.000) (0.324) (0.648) 0.931 1.255 1.579 1.903 2.227



W<sub>74</sub>—(Continued)

Int.	$\lambda$	Z.							
W I.—(Continued)									
5	4045.615	(0.000)	(0.812)	(1.624)	0.487	1.299	2.111	2.923	3.735
8	4008.769	(0.000)	(0.312)	(0.624)	(0.936)	0.853	1.171	1.483	1.795
		2.107	2.419	2.731					
5	3867.986	(0.000)	(0.433)	(0.865)	(1.298)	0.405	0.838	1.270	1.703
		2.136	2.659	3.001					
5	3846.225	(0.000)	(0.280)	0.976	1.256	1.536			
5	3835.058	(0.332)	(0.663)	0.251	1.583	1.914	2.246		
5	3768.448	(0.926)	1.636	2.562					
6	3707.929	(0.737)	(1.474)	(2.211)	0.100	0.637	1.374	2.111	2.848
		3.585							
8	3617.522	(0.440)	(0.880)	(1.321)	0.891	1.331	1.771	2.211	2.652
		3.092							
4	3311.389	(0.000)	(0.575)	(1.150)	1.153	1.728	2.303	2.878	3.453
5	2964.520	(0.000)	(0.545)	(1.090)	1.225	1.770	2.315	2.868	3.414
8	2946.992	(0.590)	(1.180)	(1.769)	0.596	1.186	1.776	2.366	2.956
		3.545							
7	2944.410	(0.000)	(0.499)	(0.997)	1.312	1.810	2.306	2.804	3.303
6	2896.445	(0.000)	(0.874)	(1.748)	0.642	1.516	2.391	3.265	4.139
3	2848.029	(1.047)	(2.094)	(3.142)	0.784	0.263	1.311	2.358	3.406
		4.453							
4	2833.634	(0.000)	(0.411)	(0.822)	(1.233)	0.474	0.885	1.296	1.707
		2.118	2.529	2.940					
5	2792.702	(1.163)	(2.326)	0.037	1.127	2.290	3.453		
W II									
3 (64)	4366.01	(0.190)	0.893	1.273					
1 (64)	4343.24	(0.517)	1.762						
	4335.39	(0.169)	(0.508)	0.875	1.213	1.553	1.891		
	4175.64	(0.237)	1.486	1.959					
3	3657.590	(0.944)	1.780						
1	3361.101	(0.932)	2.827						
3	3117.580	(0.685)	1.433						
4	2764.261	(1.466)	2.324						
	2729.59	(1.065)	1.765						
2	2658.05	(0.429)	(1.288)	0.943	1.802	2.660			

Int.	$\lambda$	$B_0$	Int.	$\lambda$	$B_0$	Int.	$\lambda$	$B_0$
	5617.03	1.204	3	4316.821	1.787	2	3177.187	1.603
	5616.16	0.934	3	4275.497	1.139	4	3163.419	1.344
	5604.31	1.730	2	4254.066	1.211	5	3041.876	1.474
	5487.74	1.807	3	4241.451	1.328	3	3039.320	1.137
	5477.82	1.406	2	4215.387	1.251	5	2997.794	1.628
3	5435.063	1.828	3	4204.415	1.214		2994.70	1.084
2	5388.023	1.612	3	4170.538	1.293	2	2936.680	1.090
1	5354.463	2.857	2	4154.678	1.741	5	2934.994	0.935
2	5259.356	2.087	3	4126.808	1.111		2925.81	0.862
3	5242.989	1.094		4125.69	1.251	3	2925.132	1.257
3	5192.725	1.046	3	4064.799	1.218	2	2918.633	1.145
4	5071.739	1.426	3	4028.798	1.591	4	2911.001	1.583
5	5054.615	1.430	3	3983.294	1.212	4	2896.010	1.610
6	5015.334	1.460	2	3979.293	1.204		2889.79	1.431
2	4986.943	1.458	1	3903.987	0.605	4	2856.033	1.585
6	4886.922	1.458	5	3809.239	0.994		2852.10	1.235
4	4729.664	1.916	2	3801.527	1.039	2	2805.930	0.863
3	4700.422	1.340	5	3641.419	1.206	3	2801.175	1.496
3	4677.710	1.200	4	3592.426	1.032	1	2740.799	0.999
2	4620.566	1.228	1	3572.477	1.450	1	2718.044	1.007
3	4543.524	1.405	1	3463.515	1.558	1	2716.323	1.528
2	4536.688	1.062	3	3429.604	1.213		2709.59	0.878
1	4492.334	1.028		3358.61	1.054		2706.72	1.221
	4441.80	1.169		3308.36	1.468		2703.49	1.280
2	4394.092	0.609		3304.46	1.195		2703.09	1.392
3	4384.868	1.228	3	3281.944	1.427	3	2697.727	2.011
3	4347.014	1.464		3262.25	1.162		2670.41	1.189
3	4330.670	1.261					2647.72	1.586

## LITERATURE

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## POLE EFFECT

HAROLD D. BABCOCK

The term pole effect is used to designate the minute change of wave-length and the marked change of character which occur for many spectral lines when light from the central region of a metallic arc is compared with that originating near the electrodes. Much evidence indicates that under suitable conditions the central region of the arc gives the normal wave-length of a line, at least to a very close approximation. The phenomenon is accordingly considered to be a modification of the normal vibration frequency by some agency which is associated with proximity to the electrodes. It is manifested to the greatest degree by lines which are diffuse and unsymmetrical, and which, in some cases, show the greatest change of wave-length with increase of pressure.

In the spectrum of iron, for which the effect has been studied more extensively than for other elements, displacements amounting to 0.045 Å toward the red and toward the violet have been observed for the lines  $\lambda 4969.93$  and  $\lambda 5133.69$  respectively, when light from near the negative pole was compared with that from the center of an ordinary iron arc. The average displacements for such lines in that region of the spectrum, however, are about one-half of the extreme value mentioned. Of 1570 iron lines examined between  $\lambda 2979$  and  $\lambda 6678$ , 286 showed displacements toward the red at the negative pole and 80 were shifted in the opposite direction. These unstable lines, as a rule, require high temperature for their excitation, are reversed only under extreme conditions, and are associated with atomic transitions involving medium and high levels of atomic energy.

Lines showing no pole effect, or at most displacements barely distinguishable from errors of observation, are in general the most symmetrical, the most easily self-reversed, and the most readily excited by low temperature sources. They are members of multiplets which are produced by atomic transitions involving the lowest energy levels in iron atoms.

Goos (3) held that for iron the displacements at the pole are due to local increase of pressure above that in other parts of the arc. The measurements of St. John and Babcock (5), however, clearly indicate that this explanation is inadequate, and the recent

work of Babcock (1) on pressure effect for iron shows conclusively that pole effect and pressure effect are distinct. A group of lines is cited which are displaced toward the violet by pole effect but in the opposite direction by increase of pressure. The pole effect for calcium has been found definitely related to spectral series by Gale and Whitney (2). Nagaoka (4) found no certain evidence of connection between pole effect and Zeeman effect.

There are many indications that pole effect is related to interatomic influences rather than to external causes directly under our control. The available data on Stark effect for iron point toward a correlation between this phenomenon and pole effect. Although no broad conclusions appear justified at present, it is possible that pole effect is nothing but Stark effect due to interatomic electrostatic fields whose efficacy depends upon various external conditions in the source.

The study of pole effect has developed a useful extension to the existing methods for classifying spectral lines, for which it affords a reliable criterion. Recognition of the rôle played by pole effect in many investigations which involve accurate knowledge of the positions of spectral lines has proved of distinct service. Mention may be made of the study of the pressure effect for terrestrial sources, and of the determination of pressures in the atmospheres of the sun and other stars, as examples. It is found in practice more satisfactory to eliminate the effect from the source of light than to attempt numerical correction for it in the results. For iron, at least, this is made feasible by suitable choice of conditions for operating the arc. The question is discussed in detail by St. John and Babcock (6), who found that enclosing the arc in a vacuum chamber caused the effect to disappear, and that under specified conditions the center of an arc at atmospheric pressure may also be used.

## LITERATURE

(For a key to the periodicals see end of volume)

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## EMISSION OF LIGHT BY SPARK DISCHARGES IN LIQUIDS

J. A. ANDERSON

The character of a spark discharge is determined by: (a) The current flowing through the spark gap. (b) The emf across the gap. (c) The material, size, shape and separation of the electrodes. (d) The medium in which the electrodes are immersed. On these, this section is concerned more especially with (a) and (d).

The following general conclusions may be regarded as fairly well established:

1. With a moderately strong current<sup>1</sup> (condensed spark discharge) in water, there is a strong continuous spectrum extending through the visible region and into the ultra-violet at least as far as  $\lambda 2300$ . Its intensity appears to be greatest in the near ultra-violet (region  $\lambda 3000$  to  $\lambda 4000$ ), and to be roughly independent of the material used as electrodes.

Superimposed on the continuous spectrum is one consisting of bright and dark lines, due chiefly to the electrodes. The low temperature arc lines appear as pure absorption lines. The high temperature arc lines, and a few of the more easily excited spark lines appear as more or less narrow absorption lines having bright edges, while the majority of spark lines are bright, generally broad, and often widened asymmetrically.

2. With decreasing current strength (smaller capacity or larger self-induction) the continuous spectrum diminishes rapidly in intensity, causing the pure absorption lines to become less conspicuous and finally to disappear. The bright lines narrow progressively, and those having bright edges gradually become narrow bright lines by the disappearance of their reversals. At low current values all lines are bright and relatively narrow, and the continuous spectrum is absent or very faint.

<sup>1</sup> As an example of a "moderately strong current," the experiments of L. and E. Bloch (2) may be cited. The capacity was 0.02 microfarad, the frequency of oscillation 570 000 cycles per sec. The potential is not stated, but must have been of the order of 20 000 volts. The maximum value of the current was accordingly about 1 400 amperes.

3. With the spark in water, the Balmer lines of hydrogen appear regularly as broad bright lines. In liquid hydrocarbons, the carbon bands appear in addition to the hydrogen lines. The air lines, so prominent in the ordinary spark spectrum, are absent.

The continuous spectrum originates in the core of the spark, and many observers have explained it as being due to hydrogen. Since Curie (3) found the continuous spectrum strongly developed with sparks in liquids containing no hydrogen, such as bromine, sulfur, etc., this explanation is probably incorrect. It is more probable that its origin is analogous to that of the continuous spectrum observed when wires are electrically exploded (see p. 434).

Bubbles of gas projected with considerable velocity from the spark are regularly observed and have sometimes been ascribed to electrolysis. Smith (15) was able to show that the quantity of gas liberated is many times too great to be accounted for in this way.

The condensed spark in water using electrodes of carbon or some of the metals is frequently used as a convenient source of continuous ultra-violet radiation, in the study of absorption spectra. A quartz window and a continuous renewal of the water surrounding the spark are necessary; see also (1, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 16, 17, 18).

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## ELECTRICALLY EXPLODED WIRES

J. A. ANDERSON

A fine metallic wire a few centimeters in length, weighing 1 or 2 mg, is placed in the discharge circuit of a large condenser. During the discharge the wire is heated and vaporized so rapidly that the earlier observers of the phenomenon (2, 4) described it as an explosion. The mechanical effects of such an explosion are fully described by Singer (4) and Nipher (2). The explanation of the phenomenon recorded by Nipher is probably incorrect, since recent work has shown that the rapid evaporation of the wire is quite competent to account for all observed effects. For quite recent work, see (7, 8, 9, 10).

**Circuit.**—The constants of a circuit used by Anderson and by Smith are: Capacity ( $C$ ) =  $10^{-6}$  farad; inductance ( $L$ ) =  $3.35 \times 10^{-6}$  henry; potential applied ( $V$ ) =  $2 \times 10^4$  volt; observed frequency of oscillation ( $N$ ) = 87 000 cycles. If  $R$  be the total resistance of the circuit, including that of the wire, or of the vapor formed from it, the value of the current ( $i$ ) at any time ( $t$ ) is given by equation (1)

$$i = V \sqrt{\frac{C}{L}} \cdot e^{-\frac{Rt}{2L}} \sin 2\pi Nt \quad (1)$$

$$= 10\,900 e^{-\frac{Rt}{2L}} \sin 2\pi Nt \text{ amp.}$$

The rate of development of heat energy in the wire is given by  $i^2 r$ , and its maximum value is shown by the experiments to be above  $10^7$  watt.

**Spectrum.**—If the wire is in open air the spectrum consists of a moderately strong continuous background upon which is superposed a system of bright and dark lines. The latter are low and moderate temperature arc lines while the former are either spark or high temperature arc lines. If the wire is confined between two parallel planes placed 2 to 10 mm apart, few, if any, bright lines appear, the spectrum being continuous, with numerous absorption lines. All arc lines and many spark lines especially those of wavelength shorter than  $\lambda 3000$  are dark in the spectrum of an iron wire. The absolute brightness of the continuous spectrum is approximately equal to that of a black-body at  $20\,000^\circ\text{C}$ .

**Variation of Spectrum with Time (5).**—During the first half oscillation the spectrum is continuous and without bright lines, but all arc lines and many belonging to the spark spectrum appear as absorption lines. In the succeeding half oscillation bright lines appear gradually, the enhanced lines first, followed in order by the high and medium temperature arc lines. In the later stages of the explosion, when the oscillations of the circuit are no longer discernible, even the low temperature arc lines appear bright.

**Pressure.**—In an open air explosion the pressure,<sup>1</sup> which initially is high, reaches a value of from 4 to 2 atm. at the end of the first half cycle, depending upon the size of wire employed. During the second half cycle it falls to a value not very much above that of the atmosphere. When the explosion is partially confined, the pressure falls more slowly, and is likely to be considerably above 1 atm. even during the second cycle. Hence it follows that at these high temperatures the spectrum is essentially continuous at pressures above 4 atm.; from 4 down to about 2 atm. the continuous spectrum diminishes somewhat in intensity, and below 2 atm. it weakens rapidly. Anderson (1) has shown that the vapors emitting a continuous spectrum have a high opacity, so that they appear to behave very much like a black-body.

<sup>1</sup> Computed from the measured values of mass and volume, assuming a temperature of  $20\,000^\circ\text{C}$ .

## LITERATURE

(For a key to the periodicals see end of volume)

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## PHOTOMETRIC STANDARDS

E. C. CRITTENDEN

The standards of candlepower on which all precise photometry is based are groups of carbon-filament electric incandescent lamps maintained in several national laboratories. These lamps are burned at temperatures below those of ordinary operation so that they change very slowly with use. Since 1909 the laboratories of France, Great Britain, and the United States of America have thus maintained a common unit of candlepower variously known as the international candle, British candle; and bougie décimale. This unit, together with the procedure for maintaining it until a reproducible primary standard shall be evolved, has been accepted by the International Commission on Illumination, which includes representatives of Belgium, Italy, Spain, and Switzerland, in addition to the three countries named above. It is also used by the national laboratories of Japan and Russia, and has been adopted by the national standards committees in Australia, Canada, Czechoslovakia, Poland, and Sweden.

The Hefner candle, the unit used in the Germanic countries, is 0.9 of the international candle, this ratio being exact within the limits of accuracy with which comparisons have been made. The legal primary standard on which this unit is based is the Hefner lamp burning amyl acetate, but the light produced by any flame depends on atmospheric conditions. The precise value of the

Hefner unit actually used was determined (3) in 1895 by comparisons between the flame lamps and electric lamps, and in recent years has been maintained by the electric standards, the flame standard serving as a check which would detect significant changes in the electric reference standards. No drift of the latter amounting to as much as 1 % has been found (2, 3).

Secondary standards of the more recent types of electric incandescent lamps (tungsten-filament vacuum and gas-filled lamps) have been established by different procedures in the several national laboratories, and there are differences as large as 3 or 4 % between the values assigned to them. The adjustment of these differences depends upon the acceptance of a standard method of comparing lights of different colors. Experiments and comparative measurements leading toward such an agreement are in progress.

While flame standards of candlepower are now little used, individual lamps of two types (Hefner, and Vernon-Harcourt 10-candle pentane) are tested and certified by the national laboratories. The variation of their intensity with atmospheric conditions is commonly represented by an equation of the following form:

$$I = I_0[1 + a(e_0 - e) - c(760 - b)],$$



where  $e$  is the humidity expressed in liters of water vapor per cubic meter of dry air,  $e_0$  is a normal humidity,  $b$  is the barometric pressure in millimeters of mercury,  $I_0$  is the intensity (candle-power) of the particular lamp under normal atmospheric conditions, and  $I$  is the intensity under the conditions represented by observed values of  $e$  and  $b$ ; it is assumed that variations of room temperature have a negligible effect. The accepted values of the constants are as follows:

Lamp	$e_0$	$a$	$c$	Lit.
Hefner.....	8.8	0.0055	0.00015	(3, 6)
Pentane:				
Great Britain.....	8.0	0.0063	0.0008	(1, 4)
United States.....	8.0	0.0057	0.0006	(5, 6, 7)
Japan.....	8.0	0.0064		(8)

The differences in the values of  $a$  for the pentane lamp arise from the fact that this "humidity factor" includes a temperature effect and that seasonal variations of humidity have a systematic relation to temperature which is nearly the same in England and

Japan, but different in America. The real humidity factor is 0.0052; this combined with a temperature term,  $+0.001(15 - t)$ , brings observed results in the three countries into complete accord;  $t$  = room temperature, °C. The variation with barometric pressure is not actually linear, but over the range of natural pressure changes either the British or American coefficient gives results correct within the accuracy with which the lamp will reproduce its values.

For very complete bibliography, see (9).

## LITERATURE

(For a key to the periodicals see end of volume)

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## PHOTOMETRIC FILTERS

E. C. CRITTENDEN

**Introduction.**—In visual photometry, filters are used (1) to equalize the intensity or the color of the two lights to be compared, (2) to test the characteristics of observers, (3) to transmit a spectral band so chosen that the ratio of its intensity to the integral light is the same for each of the lights (method of Crova). The Crova method can give correct results only when the filter is chosen in accordance with the spectral distribution of the particular sources to be compared. It is more convenient to use color equalizing filters, as they can be produced much more easily and no error is introduced by a failure in exactly equalizing the colors of the lights to be compared.

**Equalizing Filters.**—The color filters most commonly used are blue glasses and dyed gelatin films of a yellowish or amber tint. These are not reproducible; individual filters must be calibrated.

Continuously variable color filters using the rotatory dispersion of quartz plates between nicol prisms have been devised. The relative transmissions of these can be accurately calculated; see (5, 9).

Reproducible color-equalizing filters of known transmissions can be prepared from the following stock solutions. (A) Yellow solution: 100 g  $\text{Co}(\text{NH}_4)_2(\text{SO}_4)_2 \cdot 6\text{H}_2\text{O}$  + 0.733 g  $\text{K}_2\text{Cr}_2\text{O}_7$  + 10  $\text{cm}^3$   $\text{HNO}_3$  ( $d = 1.05 \text{ g/cm}^3$ ) +  $\text{H}_2\text{O}$  to make 1 l of solution at 20°C. To dilute, use  $\text{H}_2\text{O}$ .

(B) Blue solution: 50 g  $\text{Ni}(\text{NH}_4)_2(\text{SO}_4)_2 \cdot 6\text{H}_2\text{O}$  + 10 g  $(\text{NH}_4)_2\text{SO}_4$  + 55  $\text{cm}^3$   $\text{NH}_4\text{OH}$  ( $d = 0.90 \text{ g/cm}^3$ ) +  $\text{H}_2\text{O}$  to make 1 l of solution at 20°C. To dilute, use aqueous solution of 10 g  $(\text{NH}_4)_2\text{SO}_4$  per l of solution.

These solutions suitably diluted are used to equalize various color differences. The following transmission data refer to a flicker photometer using a 2° field and an effective brightness of 2.5 millilambert. Transmission measurements made with the usual Lummer-Brodhun field (about 8° by 15°) give a somewhat higher transmission for the blue, and lower for the yellow solution.

For the light from a standard 4 watt-per-candle carbon filament lamp (color temperature about 2077°K), the transmission of the diluted yellow solution is given by  $\log_{10} T = -0.245C^{0.9}$ , and of the blue by  $\log_{10} T = -0.539C^{1.02}$ , where  $C$  = concentration =

number of  $\text{cm}^3$  of stock solution (A or B) per  $\text{cm}^3$  of the diluted solution, and  $T$  = relative transmission of 1 cm of solution at 20°C =  $\tau_s/\tau_w$ , where  $\tau_w$  = transmission of a 1-cm cell having colorless glass walls and filled with clear  $\text{H}_2\text{O}$  at 20°C, and  $\tau_s$  = transmission of same cell filled with the diluted solution at 20°C. Transmission =  $L_2/L_1$  where  $L_1[L_2]$  = light incident upon front [leaving rear] face of cell.

For the light from a source with a spectral distribution of light like that of a black-body at a temperature  $>2077^\circ\text{K}$  the transmission of the yellow solution, when adjusted to give a color match with the 4 watt-per-candle carbon lamp, is given by  $\log_{10} T = -0.366C^{1.05}$ ; see (1, 2, 3, 8).

**Filters for Testing Observers.**—For a normal or average observer using a flicker photometer under standard conditions and the light from a 4-watt-per-candle lamp, the two following aqueous solutions have equal transmissions at 20°C when contained in 1-cm cells of colorless glass. Yellow solution: 72 g  $\text{K}_2\text{Cr}_2\text{O}_7$  to 1 l solution at 20°C. Blue solution: 57 g  $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$  to 1 l solution at 20°C; see (2, 4, 6, 7).

**Filters for Physical Photometers.**—Any receiver which responds to radiant energy in a definite and quantitative manner can be used as a photometer if covered by such a filter that the resultant spectral sensitivity curve is like that of the eye. All such known receivers which are accurately reproducible are non-selective, and for such the best filter appears to be a 1-cm thickness of the following solution, supplemented by clear  $\text{H}_2\text{O}$  sufficient to absorb practically all the infra-red (about 2 cm): 61.25 g  $\text{CuCl}_2 \cdot 2\text{H}_2\text{O}$  + 14.5 g  $\text{Co}(\text{NH}_4)_2(\text{SO}_4)_2 \cdot 6\text{H}_2\text{O}$  + 1.9 g  $\text{K}_2\text{CrO}_4$  +  $\text{H}_2\text{O}$  to make 1 l; see (4, 6).

## LITERATURE

(For a key to the periodicals see end of volume)

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## MECHANICAL EQUIVALENT OF LIGHT

HERBERT E. IVES

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DEFINITIONS<sup>1</sup> AND SYMBOLS

1. The *efficiency of a source* is the ratio of the total luminous flux to the total power consumed (A. E. S. C. 46)( $E_s$ ).

2. The *luminous efficiency of the radiation* from any source is the ratio of the luminous flux to the radiant flux from the source (A. E. S. C. 22)( $E_r$ ).

3. The *visibility factor for the radiation* of a particular wave-length is the ratio of the luminous flux at that wave-length to the corresponding radiant flux (A. E. S. C. 18)( $V_\lambda$ ). (It is the luminous efficiency of monochromatic radiation of that wave-length.)

4. The *relative luminous efficiency of a source or a radiation* is the ratio of its efficiency to that of monochromatic radiation of maximum efficiency (about  $\lambda = 0.555\mu$ )( $E_{sr}$ ,  $E_r$ ).

5. The *relative visibility factor* for a particular wave-length is the ratio of the visibility factor for that wave-length to the maximum value of the visibility factor (A. E. S. C. 19)( $V_{\lambda r}$ ). (It is the relative luminous efficiency of monochromatic radiation of that wave-length.)

6. *Mechanical equivalent of the light* of a given radiation = power radiated per unit of luminous flux emitted = reciprocal of the luminous efficiency of the radiation.

7. *Least mechanical equivalent of light* = mechanical equivalent of monochromatic radiation of greatest luminous efficiency (about  $\lambda = 0.555\mu$ )( $m$ ).

If  $L$  = total luminous flux,  $R$  = total radiant flux,  $L = \int_0^\infty L_\lambda d\lambda = \int_0^\infty V_\lambda R_\lambda d\lambda$ ,  $R = \int_0^\infty R_\lambda d\lambda$ ,  $E = L/R$ ,  $E_r = E/(E_\lambda)_{\max.} = E/(V_\lambda)_{\max.} = mE$ .

The value found for  $L$ , and hence for  $m$ , depends to some extent upon the conditions of observation (intensity of illumination, size of field, type of photometer, etc.). As there is no general agreement regarding what these conditions should be, the following data have a tentative character and those obtained by different observers are not always comparable.

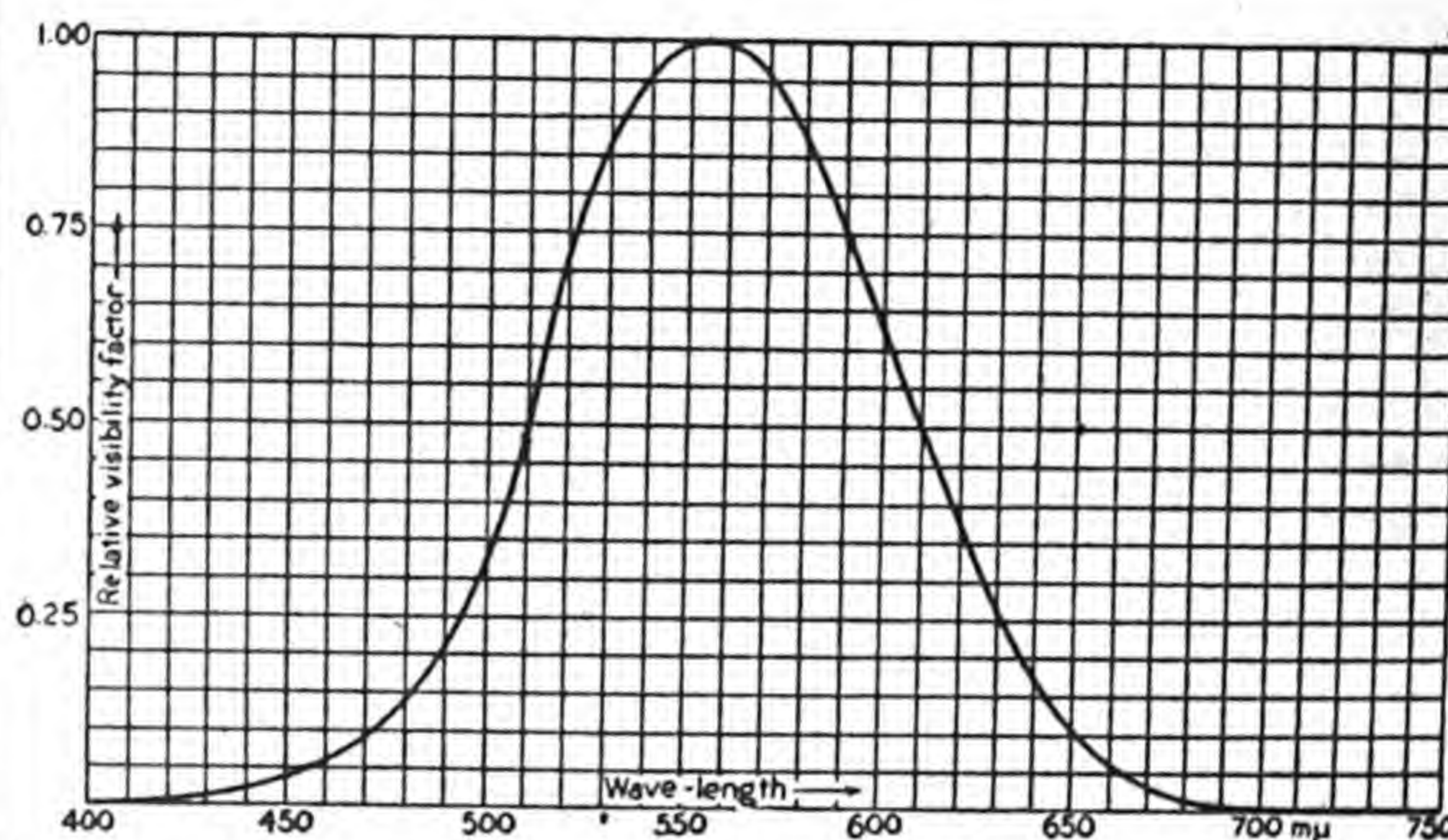
TABLE 1.—RELATIVE VISIBILITY FACTOR ( $V_{\lambda r}$ ) OF MONOCHROMATIC RADIATION (7)

These values, applying to photometric fields of relatively high brightness, have been tentatively adopted by the International Commission on Illumination. They are accurately represented by the formula:  $V_{\lambda r} = 0.9896(R_1 e^{1-R_1})^{200} + 0.0820(R_2 e^{1-R_2})^{550} + 0.0650(R_3 e^{1-R_3})^{2000} + 0.0375(R_4 e^{1-R_4})^{630}$ , where the  $R$ 's are pure numbers defined by the equations  $\lambda = \frac{0.555}{R_1} \mu = \frac{0.607}{R_2} \mu =$

<sup>1</sup> The definitions, that are followed by the letters A. E. S. C. and a number, are those given by the American Engineering Standards Committee, and follow closely those adopted by the International Illumination Commission. The remaining quantities are not defined by those bodies, and it has accordingly been necessary to complete the list by definitions so worded as to be consistent with those adopted. Various authorities differ in terminology, and the definitions here given are not those elsewhere used and advocated by the writer.

$$\frac{0.523}{R_3} \mu = \frac{0.467}{R_4} \mu; \lambda \text{ is the wave-length of the radiation considered.}$$

Mechanical equivalent =  $m/V_{\lambda r}$ ,  $m$  = the least mechanical equivalent of light = 0.00161 watt/lumen; luminous efficiency of the radiation =  $V_{\lambda r}/m$ . Unit of  $\lambda = 0.001\mu = 10 \text{ \AA}$ ; of  $V_{\lambda r} = 1\%$ , see Fig. 1; see also (2, 9, 11, 18, 19, 20).

FIG. 1.—Relative visibility factor of monochromatic radiation (7). Relative visibility factor = relative luminous efficiency.  $1\mu = 10^{-7} \text{ cm} = 10 \text{ \AA}$ . (See Table 1.)

$\lambda$	$V_{\lambda r}$	$\lambda$	$V_{\lambda r}$	$\lambda$	$V_{\lambda r}$
400	0.04	530	86.2	660	6.1
410	0.12	540	95.4	670	3.2
420	0.40	550	99.5	680	1.7
430	1.16	560	99.5	690	0.82
440	2.3	570	95.2	700	0.41
450	3.8	580	87.0	710	0.21
460	6.0	590	75.7	720	0.105
470	9.1	600	63.1	730	0.052
480	13.9	610	50.3	740	0.025
490	20.8	620	38.1	750	0.012
500	32.3	630	26.5	760	0.006
510	50.3	640	17.5		
520	71.0	650	10.7		

TABLE 2.—LEAST MECHANICAL EQUIVALENT OF LIGHT

Value for green Hg-line,  $\lambda = 5461 \text{ \AA}$ , was derived from direct radiometric and photometric measurements; that for black-body (B. B.), from photometric measurements and computation of total radiation, using indicated values of  $\sigma$  and  $C_2$ ; that for carbon lamp (C. L.), from measurement with and without a luminous efficiency screen. In column  $V_{\lambda r}$  is indicated the relative visibility factor used in the reduction;  $m_0[m]$  = value of the least mechanical equivalent as reported by observer (as corrected to basis of Table 1,  $\sigma = 5.709 \times 10^{-12} \text{ watt cm}^{-2} \text{ deg}^{-4}$ , and  $C_2 = 14\,330 \text{ micron degree}$ ). The value found for  $m$  depends to some extent upon the conditions of observation (illumination, size of field, type of photometer), and there is no general agreement regarding what these conditions should be. Unit of  $\sigma = 10^{-12} \text{ watt cm}^{-2} \text{ deg}^{-4}$ ; of  $C_2 = \text{micron degree}$ ; of  $m_0$  and  $m = 0.001 \text{ watt lumen}^{-1}$ .

Source	$T$ , °K	$\sigma$	$C_2$	$V_{\lambda r}$	$m_0$	$m$	Lit.
5461 $\text{\AA}$	(Assumed to be $\lambda$ of max. efficiency)			1.44	1.42	(1)	
5461 $\text{\AA}$				1.59	1.61	(14, 15)	
and C. L.				I (11)			



TABLE 2.—(Continued)

Source	T, °K	$\sigma$	$C_1$	$V_{\lambda r}$	$m_0$	$m$	Lit.
5461 Å	(Observations of (14, 15))			C. E. (2)	1.61	1.61	(3)
B. B.		5.7	14 350	H. F. C. (9)	1.50		(9)
B. B.		5.7	14 350	C. E. (2)	1.65*		(3)
B. B.	1 336(Au)	†	14 300	I (11)	1.68		(8)
B. B.	1 336(Au)	†	14 350	I (11)	1.59	1.62	(8)
B. B.	2 035(Pt)	5.7	14 330	G. T. (7)	1.61	1.61	(13)
Recommended value					1.61		

\* Recomputation of observations (9); here corrected to agree with their later values (10). †  $C_1 = 3.704 \times 10^{-12}$  watt cm<sup>2</sup>.

TABLE 3.—LUMINOUS CHARACTERISTICS OF A BLACK-BODY

The relative luminous efficiency ( $E_r$ ) of the radiation from the black-body is computed on the bases of Table 1 and the radiation constants ( $\sigma = 5.709 \times 10^{-12}$  watt cm<sup>-2</sup> deg<sup>-4</sup>,  $C_2 = 14 330$  micron deg) chosen for I. C. T. (cf. (17)).  $E_r = \left( \int_0^\infty V_{\lambda} J_{\lambda} d\lambda \right) \div \left( \int_0^\infty J_{\lambda} d\lambda \right)$ ;  $J_{\lambda}$  = monochromatic intensity of the radiation.  $B$  = brightness if least mechanical equivalent = 0.00161 watt lumen<sup>-1</sup>;  $B = b \times 10^n$ ;  $E_r = e \times 10^{n'}$ . Unit of  $B = 1$  candle cm<sup>-2</sup>.

T, °K	$E_r$		$B^*$	
	$e$	$n'$	$b$	$n$
1 200	6.02	-6	1.41	-2
1 400	5.57	-5	2.42	-1
1 600	2.82	-4	2.08	0
1 700	5.41	-4	5.10	0
1 750	7.26	-4	7.69	0
1 800	9.57	-4	1.13	+1
1 850	1.24	-3	1.64	1
1 900	1.58	-3	2.32	1
1 950	1.98	-3	3.23	1
2 000	2.46	-3	4.44	1
2 050	3.01	-3	5.96	1
2 100	3.64	-3	7.98	1
2 150	4.36	-3	1.05	2
2 200	5.17	-3	1.37	2
2 250	6.06	-3	1.75	2
2 300	7.06	-3	2.23	2
2 350	8.16	-3	2.81	2
2 400	9.35	-3	3.50	2
2 450	1.07	-2	4.33	2
2 500	1.20	-2	5.31	2
2 550	1.35	-2	6.45	2
2 600	1.51	-2	7.80	2
2 650	1.68	-2	9.34	2
3 000	3.09	-2	2.83	3
4 000	8.07	-2	2.33	4
5 000	1.190	-1	8.40	4
6 000	1.353	-1	1.98	5
7 000	1.352	-1	3.67	5
8 000	1.258	-1	5.82	5
10 000	9.87	-2	1.115	6

\* Between  $T = 1700$  and  $2650^\circ\text{K}$  these values agree satisfactorily with observations of (6, 10), as recomputed to basis  $C_2 = 14 330$  but are a little greater; greatest difference is 1.2 %.

TABLE 4.—LUMINOUS EFFICIENCY OF RADIATION FROM ELECTRICALLY EXCITED GASES AND VAPORS (4); cf. (5)

$E$  = luminous efficiency;  $E_r$  = relative luminous efficiency; color = color of light emitted;  $p$  = probably. Unit of  $E = 1$  lumen/watt; of  $E_r = 1\%$ .

Gas	Color	$E$	$E_r$
A	Red.....	0.24	0.04
As		0	0

TABLE 4.—(Continued)

Gas	Color	$E$	$E_r$
Br	Blue-white.....	0.06	0.01
Cd	Blue-white.....	1.6	0.26
Cl	Blue.....	0.08	0.01
Cs	Blue-white.....	<0.4	<0.06
F		0.1 $p$	0.02 $p$
H	Red.....	0.08	0.01
He	White.....	4.4	0.71
Hg	Blue-green*	11	1.82
Hg	Blue-white†	126	20.3
I	White.....	1.1	0.18
K	Purple.....	1.8	0.28
Kr	Violet.....	<0.6 $p$	<0.1 $p$
Li	Red.....	†	
N	Yellow-orange.....	1.6	0.26
Na	Yellow.....	214	34
Ne	Red-orange.....	23.0	3.6
O	Blue-white.....	0.05	0.01
P	Blue-white.....	§	
Rb	Red.....	0.24	0.04
S	Blue-white.....	0.89	0.14
Se		0 $p$	0 $p$
Tl	Green-white.....	0.08	0.01
Xe	Blue-green.....	<1 $p$	<0.20 $p$
Zn		0.13	0.02

\* Without condenser. † With 0.14 microfarad condenser in parallel with tube.

‡ Vapor pressure too low for continuous discharge. § Too low to measure.

TABLE 5.—RELATIVE LUMINOUS EFFICIENCY ( $E_r$ ) OF RADIATION FROM COMMERCIAL ILLUMINANTS (16)

Unit of  $E_r = 1\%$

Source	Description	$E_r$
Incandescent electric lamps:		
Carbon, point source.....	4 w.p.c., 99 volt	0.45
Tungsten, vacuum.....	9.16 volt, 1.25 w.p.c.	1.65
Tungsten, vacuum.....	97.0 volt, 1.1 w.p.c.	1.84
Tungsten, vacuum.....	102.6 volt, 1 w.p.c.	1.99
Tungsten, nitrogen.....	6.6 amp., 0.65 w.p.c.	2.93
Mercury arc.....	1.7 amp., Pfund type	30.5
Nernst glower.....	0.8 amp., stereopticon type	1.08
Gas lamps:		
Incandescent mantle.....	0.25% ceria	0.5
Incandescent mantle.....	0.25% ceria	0.7
Incandescent mantle.....	0.75% CeO <sub>2</sub> , solid chimney	1.2
Incandescent mantle.....	0.75% CeO <sub>2</sub> , perforated chimney	1.26
Incandescent mantle.....	2% ceria	0.8
Open burner.....		0.19
Standard candle.....	Sperm	0.24

TABLE 6.—EFFICIENCIES OF COMMERCIAL ILLUMINANTS (12)

Rating = commercial rating of lamp;  $E_s$  = luminous efficiency of lamp;  $E_{sr}$  = relative luminous efficiency of lamp =  $mE_s$ ,  $m$  = least mechanical equivalent of light; w.p.c. = watts per mean horizontal candlepower; cp. = candlepower; amp. = ampere; D.C. [A.C.] = direct [alternating] current; BTU = British thermal unit; h.p. [l.p.] = high [low] pressure; 60 ~ = 60 cycles per second. Unit of  $E_s = 1$  lumen per watt consumed; of  $E_{sr} = 1\%$ .

Lamp	Rating	$E_s$	$E_{sr}$
Incandescent electric:			
Carbon.....	4 w.p.c.	2.6	0.42
Treated carbon*.....	1.25 w.p.c.	8	1.3
Tungsten, vacuum.....	600 cp., 20 amp., 0.5 w.p.c.	19.6	3.2



TABLE 6.—(Continued)

Lamp	Rating	$E_s$	$E_{sr}$
Incandescent electric (Cont'd)			
Tungsten, Mazda-C.....	500 watt, multiple, 7 w.p.c.	15	2.4
Electric arc:			
Carbon, open.....	9.6 amp., clear globe	11.8	1.9
Carbon, enclosed†.....	6.6 amp., D.C.	5.9	0.96
Carbon, enclosed†.....	7.5 amp., A.C.	5.6	0.91
Magnetite.....	6.6 amp., D.C.	21.6	3.5
Mercury in glass.....	40 to 70 volt, 3.5 amp.	23	3.7
Mercury in quartz.....	147 to 197 volt, 4.2 amp.	42	6.8
Flaming, ‡ enclosed:			
White, carbon.....	10 amp., A.C.	26.7	4.3
White, carbon.....	6.5 amp., D.C.	35.5	5.8
Yellow, carbon.....	10 amp., A.C.	31.4	5.1
Yellow, carbon.....	6.5 amp., D.C.	34.2	5.5
Flaming, ‡ open:			
White, inclined.....	10 amp., A.C.	29	4.7
White, inclined.....	10 amp., D.C.	27.7	4.5
Yellow inclined.....	10 amp., A.C.	41.5	6.7
Yellow, inclined.....	10 amp., D.C.	44.7	7.2
Moore nitrogen tube.....	220 volt, 60~, 113.17 ft.	5.21	0.85
Nernst lamp.....		4.8	0.77

TABLE 6.—(Continued)

Lamp	Rating	$E_s$	$E_{sr}$
Gas lamps:			
Acetylene.....	1.0 liter per hr	0.67	0.11
Incandescent, l.p.....	0.350 lumen per BTU hr <sup>-1</sup>	1.2	0.19
Incandescent, h.p.....	0.578 lumen per BTU hr <sup>-1</sup>	2.0	0.32
Open flame.....	Bray 6 in., h.p.	0.22	0.036
Petroleum lamp.....		0.26	0.04

\* Oval, anchored filament.

† Inner, light opal; outer, clear; lamp provided with street reflector. A resistance is in series with the A.C. arc.

‡ Ornamental type of lamp, clear globe, standard electrodes, series resistance.

## LITERATURE

(For a key to the periodicals see end of volume)

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## THE PROPERTIES OF PHOTOGRAPHIC MATERIALS

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## Part I

## The Photochemical Equivalent of the Silver Halides (10); cf. (9, 38, 41, 42, 43)

$\Sigma h\nu$  = sum of quanta absorbed per  $\text{cm}^2$ ,  $N_{\text{Ag}}$  = number of silver atoms produced per  $\text{cm}^2$  without development,  $N/\Sigma h\nu$  = photochemical equivalent.

Fast plate				Process plate			
$10^{-16} \times \Sigma h\nu$	$N/\Sigma h\nu$	$10^{-16} \times \Sigma h\nu$	$N/\Sigma h\nu$	$10^{-16} \times \Sigma h\nu$	$N/\Sigma h\nu$	$10^{-16} \times \Sigma h\nu$	$N/\Sigma h\nu$
0.39	0.88	3.00	0.92	0.85	0.82	5.50	0.79
0.41	0.88	6.00	0.79	0.95	0.88	6.40	0.78
0.68	0.93	8.00	0.71	1.80	1.08	9.20	0.73
0.90	1.01	8.80	0.67	2.80	1.06	11.40	0.62
0.99	0.92	9.30	0.68	3.40	0.83	22.50	0.38
1.76	0.99	13.00	0.50	4.70	0.76	30.00	0.33
2.30	0.98						

## The Silver Reduction Equivalent of Photographic Developers

By silver reduction equivalent ( $E_{\text{Ag}}$ ) is meant the number of atoms of metallic silver reduced per molecule of developer oxidized. Temperature = 20°C and Ag is added as excess AgBr except as otherwise indicated.

Grams developer	Grams alkali	Grams $\text{Na}_2\text{SO}_3$	Vol., $\text{cm}^3$	Duration of experiment	$E_{\text{Ag}}$	Lit.
1. Quinol						
1.4	$\text{K}_2\text{CO}_3$ , 20	20	ca. 300	20 min	4.3	(1)
1.4	$\text{K}_2\text{CO}_3$ , 20	20	ca. 300	20 min	5.0*	(2)
1.4	$\text{K}_2\text{CO}_3$ , 20	20	ca. 300	30 min	4.3	(3)
1.4	$\text{K}_2\text{CO}_3$ , 20	20	ca. 300	60 min	7.8	(3)
0.11	$\text{NaOH}$ , 2.2	0	25	6 hr	6.4	(14)
0.11	$\text{NaOH}$ , 2.2	0	25	6 hr	9.3†	(14)
0.11	$\text{NaOH}$ , 2.2	0	25	18 da	7.8	(14)
0.055	$\text{NaOH}$ , 2.2	0.063	25	18 da	7.8	(14)
0.055	$\text{NaOH}$ , 2.2	0.63	25	18 da	8.9	(14)
0.055	$\text{NH}_4\text{OH}$ , aq. 20†	0	40	8 da	8.0‡	(14)
0.055	$\text{NaOH}$ , 2.2	0	25	15 hr	10.5	(14)
2. Pyrogallol						
	$\text{NH}_4\text{OH}$	0			ca. 4¶	(18); cf. (37)
0.063	$\text{NaOH}$ , 2.2	0	25	1 hr	3.2	(14)
0.063	$\text{NaOH}$ , 2.2	0.315	25	1 hr	3.4	(14)
3. Pyrocatechol						
0.055	$\text{NaOH}$ , 2.2	0	25	2 hr or 21 da	4.5	(14)
0.055	$\text{NaOH}$ , 2.2	0.315	25	21 da	5.9	(14)
1.4	$\text{K}_2\text{CO}_3$ , 20	20	ca. 300	21 min	1.9	(1)
4. p-Aminophenol						
1.4	$\text{K}_2\text{CO}_3$ , 20	20	ca. 300	20 min	3.9	(1)

## Silver Reduction Equivalent.—(Continued)

Grams developer	Grams alkali	Grams $\text{Na}_2\text{SO}_3$	Vol., $\text{cm}^3$	Duration of experiment	$E_{\text{Ag}}$	Lit.
5. o-Aminophenol						
1.4	$\text{K}_2\text{CO}_3$ , 20	20	ca. 300	20 min	0.7	(1)
6. Chlorquinol						
1.9	$\text{K}_2\text{CO}_3$ , 20	20	150	1 hr	6.7	(2)
7. Quinone						
0.054	$\text{NaOH}$ , 2.2	0	25	1 hr	3.9	(14)
0.054	$\text{NaOH}$ , 2.2	0.63	25	1 hr	4.9	(14)
8. Hydroxylamine as $\text{NH}_2\text{OH} \cdot \text{HCl}$						
0.70	$\text{NaOH}$ , 25**		100	60 min	1.1	(24)
0.70	$\text{NaOH}$ , 50**		100	60 min	0.98	(24)
0.70	$\text{NaOH}$ , 12.5**		100	60 min	1.01	(24)
0.70	$\text{NaOH}$ , 12.5**		100	60 min	1.00	(24)
0.044	$\text{NH}_4\text{OH}$			60 min	2.00††	(24)
9. Hydrogen peroxide						
1.720	$\text{NaOH}$			60 min	1.00	(24)

\* Excess AgBr added progressively.

|| Ag as excess  $\text{Ag}_2\text{O}$ .†  $t = 95-100^\circ$ .¶ Ag as excess ammoniacal  $\text{AgNO}_3$ .

‡ Sp. gr. 0.9.

\*\*  $\text{cm}^3$  of 1N  $\text{NaOH}$ .§ Ag as  $\text{AgNO}_3$ , 1.7 g.†† Ag as ammoniacal  $\text{Ag}_2\text{O}$ .

It is clear that the so-called silver equivalent of a given developing agent varies with the other constituents of the developer, the temperature, duration of run, and the form and manner in which the silver is added. Gordon (3) found, further, that the equivalent varies markedly with the method of shaking. It is probable that none of the values represents an equilibrium system and all are therefore to be regarded as tentative. Lüppo-Cramer (24), believes all determinations on silver halides in absence of emulsifying substances to be without photographic significance.

## Photographic Development Velocity Functions and Constants

The rate of development may be measured by the increase of density,  $D$ , at a single exposure with time of development,  $t$ , or more satisfactorily, and in closer relation to photographic theory and practice, by the increase of gamma,  $\gamma$ , (constant or development factor) with time,  $t$ .

The function for  $(\gamma, t)$  will be of the same form as for  $(D, t)$ , provided the straight line portions of the characteristic curves (*q.v.*, p. 442) meet on the axis of exposures. If they converge to a point below the axis, as when soluble bromide is present, then if  $a$  is the depression of density at the convergence point (cf. (28)) the function for  $(D + a)$ ,  $t$  will be the same as for  $\gamma, t$ .

For some emulsions the convergence point is above the axis, in which case the function for  $\gamma, t$  should be compared with  $(D - a)$ ,  $t$ .

## FORMS OF DEVELOPMENT VELOCITY EQUATION

	Log form	Exponential form	First derivative	Lit.
1	$Kt = \log_e \frac{D_\infty}{D_\infty - D}$	$D = D_\infty(1 - e^{-Kt})$	$\frac{dD}{dt} = K(D_\infty - D)$	(37)
2	$K(t - t_0) = \log_e \frac{D_\infty}{D_\infty - D}$	$D = D_\infty(1 - e^{-K(t-t_0)})$	$\frac{dD}{dt} = K(D_\infty - D)$	(37)
3	$K(\log_e t - \log_e t_0) = \log_e \frac{D_\infty}{D_\infty - D}$	$D = D_\infty(1 - e^{-K \log_e t/t_0})$	$\frac{dD}{dt} = \frac{K}{t}(D_\infty - D) = Kt^{-1}(D_\infty - D)$	(28)
4	$\log_e K + b \log_e (t - t_0) = \log_e \log_e \frac{D_\infty}{D_\infty - D}$	$D = D_\infty(1 - e^{-K(t-t_0)^b})$	$\frac{dD}{dt} = Kb t^{b-1}(D_\infty - D)$	(44)
5	$Kt = \log_e \frac{p\xi}{p\xi - D} - \frac{d}{(d+h)(D_\infty - p\xi)} \log_e \frac{D_\infty}{D_\infty - D}$		$\frac{dD}{dt} = K \frac{b - aD}{h(D_\infty - D) + d}(D_\infty - D)$	(33)

$K$  = velocity constant of development.  $t$  = time of development in any unit selected.  $t_0$  = empirical correction for the induction period in development.  $D_\infty$  = theoretical silver image density at infinite development.  $D$  = measured silver image density at time,  $t$ .  $a, b, d, h$  = empirical constants.  $p\xi = D_\infty$  as used in 1-4. In 5,  $D_\infty$  represents the mass (unknown) of the latent image.

Equation 1 holds only for simple iron oxalate development, and for pyrogallol-soda (fairly). Equation 2 is of much wider application but in many cases fails in the advanced stages of alkaline development. Equation 3 has been found generally satisfactory by Nietz (28) in his extensive experimental work.

Equation 4 is equally satisfactory and sometimes holds over a wider range but is more difficult of application. Equation 5 is of theoretical significance as being based upon the conception of the reversibility of the development process; it contains too many undeterminable terms to be practically useful.



### DEVELOPMENT VELOCITY CONSTANTS AND RELATED DATA FOR VARIOUS DEVELOPERS ON THE SAME EMULSION (28)

Each developer contained 50 g Na<sub>2</sub>SO<sub>3</sub>, 50 g Na<sub>2</sub>CO<sub>3</sub> and 1.19 g KBr per liter. Developing agents marked with an asterisk were of high purity, and others, excepting only edinol, duratol and eikonogen, which were the commercial product, were of better than commercial quality.  $D_{\infty}$ ,  $t_0$ ,  $K$  as previously defined.  $\gamma_{\infty}$  = theoretical plate contrast reached on infinite development.

Developing agents all at 0.05 molal concn.	Constants of Eq. 3			
	$D_{\infty}$	$\gamma_{\infty}$	$t_0$ , min	$K$
Toluquinol.....	4.40	1.67	1.35	0.63
Diaminophenol + alkali*	4.2	1.40	0.6	0.60
<i>p</i> -Aminophenol*	4.2	1.84	1.0	0.44
<i>p</i> -Amino- <i>m</i> -cresol.....	4.0	1.33	1.24	0.72
Methyl- <i>p</i> -amino- <i>o</i> -cresol.....	4.0	1.26	0.33	0.60
Pyrogallol*	4.0	1.22	0.78	0.57
Chlorquinol*	4.0	1.82	1.3	0.52
Quinol*	3.8	1.26	1.80	0.95
Dibromquinol.....	3.8	1.27	0.80	0.80
<i>p</i> -Amino- <i>o</i> -cresol.....	3.8	1.27	0.87	0.70
Bromquinol.....	3.8	1.73	1.27	0.66
Eikonogen.....	3.8	1.43	1.7	0.47
Monomethyl- <i>p</i> -aminophenol*	3.6	1.50	0.70	0.58
Diaminophenol, no alkali.....	3.6	1.63	0.36	0.55
Pyrocatechol.....	3.6	1.68	0.60	0.52
Dichlorquinol.....	3.6	1.29	0.80	0.53
Edinol.....	3.6	1.22	1.9	0.46
Phenylhydrazine, no alkali.....	3.5		8.5	0.03
<i>p</i> -Dimethylaminophenol.....	3.2	1.18	0.75	0.61
Ferrous oxalate*	3.1	1.29	0.97	0.55
Benzyl- <i>p</i> -aminophenol (duratol).....	2.4	0.98	2.27	0.34
<i>p</i> -Phenylenediamine.....	1.7	0.58	2.10	0.34

#### The Temperature Coefficient of Development

Sheppard and Mees (36) found that in the case of ferrous oxalate development the temperature-development velocity relation was represented quite accurately by the integrated form of the Van't Hoff reaction isochore:  $\log K = -\frac{A}{T} + C$ , where  $K$  = development velocity constant,  $A$ ,  $C$  = experimentally determined characteristic constants,  $T$  = absolute temperature.

The temperature coefficient for any development process for which the above relation holds is given by:

$$\alpha_{10} = \frac{K_T + 10}{K_T}$$

Ferguson (11) has proposed and successfully applied to general alkaline development the formula

$$\log b = \frac{\log M - \log m}{\Delta t}$$

in which  $b$  = temp. coeff. for 1°C.  $M$ ,  $m$  = time of development giving equal factors at the higher and lower temperatures, respectively.  $\Delta t$  = temp. difference in °C.

#### TEMPERATURE COEFFICIENT OF DEVELOPMENT

Developing agent	Plate or emulsion	$\alpha_{10}$	Lit.
Ferrous oxalate.....	"A"	1.60	(37)
Ferrous oxalate.....	"B"	1.90	(37)
Ferrous oxalate.....	"C"	1.70	(37)
Hydroxylamine.....	"C"	2.00	(37)
Quinol.....	"B"	2.20	(37)
Quinol.....	"C"	2.80	(37)
Quinol (tabloid).....		2.25	(40)
<i>p</i> -Aminophenol.....	"C"	1.50	(37)
Metol.....	"C"	1.25	(37)
Pyrocatechol.....	"B"	2.80	(37)
Glycine (tabloid).....		2.3	(40)
Metol-quinol.....		1.9	(40)

#### TEMPERATURE COEFFICIENT.—(Continued)

Developing agent	Plate or emulsion	$\alpha_{10}$	Lit.
Rytol (tabloid).....		2.2	(40)
Rodinal ( <i>p</i> -aminophenol).....		1.9	(40)
Pyrogallol soda, no bromide.....		1.5	(40)
Pyrogallol soda with bromide.....		1.9	(40)
Pyrogallol soda, no bromide.....	Wratten Pan-chromatic	2.0	(20)
Pyrogallol soda, no bromide.....	Imperial Ordinary	1.71	(12)
Pyrogallol soda, no bromide.....	Wratten Instantaneous	1.68	(12)
Pyrogallol soda, no bromide.....	Ilford Empress	1.55	(12)
Pyrogallol soda, no bromide.....	Imperial Special Rapid	1.76	(12)
Pyrogallol soda, no bromide.....	Ilford Special Rapid	1.85	(12)
Pyrogallol soda, no bromide.....	Wellington Rapid Special	1.99	(12)
Pyrogallol soda, no bromide.....	Barnet Extra Rapid	2.01	(12)
Pyrogallol soda, no bromide.....	Monarch	1.9	(12)
Pyrogallol soda with 0.1% bromide*	Barnet Extra Rapid	2.01	(12)
Pyrogallol soda with 0.1% bromide*	Ilford Empress	2.09	(12)

\* Ferguson's results (12) for bromided pyrogallol, only two of which are quoted for illustration, gave a temp.-coeff. of approximately 2 for all the plates tested, irrespective of the unbromided values. Bromide apparently stabilizes the temp.-coeff., eliminating the emulsion effect observed by Sheppard and Mees (37). Watkins records a like conclusion (40). The temp.-coeff. of a developer is in general independent of its dilution.

#### Suggested Watkins' Factors (40)

Multiplication of the time of first appearance of the image by the suggested factor should give a negative of average contrast; the factor may then be adjusted to fit the peculiar requirements of the individual worker. Where the factor is evenly divisible into 60, a divisor is given:  $\frac{\text{Time of appearance in seconds}}{\text{Divisor}} = \text{correct development time in minutes.}$

Except in the case of pyrogallol and amidol the factor is independent of the developer strength. Variation in alkali does not alter the factor.

For sky, snow, and water negatives use a somewhat smaller factor, e.g.,  $\frac{2}{3}$  normal. For negatives devoid of high lights calculate development time on the basis of  $\frac{3}{5}$  of time of appearance.

Developer	grams/fl. oz. developer		mg/ml developer		Factor (and divisor)
	Pyro	Bromide	Pyro	Bromide	
Pyrogallol with Na <sub>2</sub> CO <sub>3</sub> .....	1	0	2.16	0	18
	2	0	4.32	0	12 (div. 5)
	3	0	6.48	0	10 (div. 6)
	4	0	8.64	0	8
	5	0	10.80	0	6.5
Pyrogallol with Na <sub>2</sub> CO <sub>3</sub> .....	1	2.16	0.25	0.54	9
	2	4.32	0.5	1.08	5 (div. 12)
	3	6.48	0.75	1.62	4.5
	4	8.64	1	2.16	4 (div. 15)
	8	17.28	2	4.32	3.25
Adurol.....					5 (div. 12)
Kachin.....					10 (div. 6)
Pyrocatechol.....					10 (div. 6)
Pyrocatechol cristoid.....					30 (div. 2)
Quinol (minimum bromide).....					5 (div. 12)



Developer	Factor (and divisor)
Quinol (maximum bromide).....	4.5
Eikonogen.....	9
Metol (Elon).....	30 (div. 2)
Glycine with Na <sub>2</sub> CO <sub>3</sub> .....	8
Glycine with K <sub>2</sub> CO <sub>3</sub> .....	12 (div. 5)
p-Aminophenol.....	16
Amidol (2 grains/fl. oz).....	18
Rodinal.....	40
Ortol.....	10 (div. 6)
Diogen.....	12 (div. 5)
Edinol.....	20 (div. 3)
2, 4-Diaminophenol (dianol).....	60 (div. 1)
Quinomet.....	30 (div. 2)
Metol-quinol*.....	14

\* The factors of combination developers depend upon the proportion of the two constituents, and when they contain pyrogallol, no rule can be given for finding the factor when diluted. The use of potash as an alkali instead of soda seems, with most developers, to require factors from one-quarter to one-half longer.

### Reduction Potentials of Developers

The reduction potentials of developers were originally defined electrochemically (4)<sup>1</sup> but it has been shown that stable potentials, corresponding to equilibrium mixtures of reducer/oxidation-products, are not obtainable for alkaline organic developers (35). Relative reduction potentials were defined by Sheppard by relation to the theoretical equilibrium in development, and an empirical method of determining them worked out (34).

The relative reduction potentials  $\pi_{Br}$ , determined by the bromide-depression method of Sheppard as applied by Nietz (28) is defined by the equation

$$\pi_{Br} = kC_0$$

where  $C_0$  is the concentration of KBr required to produce an initial depression in the intersection point of the Hurter and Driffield curves;  $k$  is a constant as yet undetermined.

### RELATIVE REDUCTION POTENTIALS OF PHOTOGRAPHIC DEVELOPERS (28)

Developer	Mole/l	$\pi_{Br}$ , hydroquinol = 1.0
Ferrous oxalate.....	0.10	0.3
p-Phenylenediamine hydrochloride.....	0.05	0.3
p-Phenylenediamine hydrochloride + alkali.....	0.05	0.4
Methyl-p-phenylenediamine hydrochloride.....	0.05	0.7
Quinol.....	0.05	1.0
p-Phenylylglycine.....	0.05	1.6
Hydroxylamine hydrochloride.....	0.10	2.0
Toluquinol.....	0.05	2.2
Methyl-p-phenylenediamine hydrochloride + alkali.....	0.05	3.5
p-Aminophenol hydrochloride.....	0.05	6.0
Chlorquinol.....	0.05	7.0
p-Amino-o-cresol.....	0.05	7.0
p-Dimethylaminophenol sulfate.....	0.05	10.0
Pyrogallol.....	0.05	16.0
Monomethyl-p-aminophenol sulfate.....	0.05	20.0
Bromquinol.....	0.04	21.0
Methyl-p-amino-o-cresol.....	0.05	23.0
2, 4-Diaminophenol.....	0.05	30 to 40

### The Photometric Constant of the Developed Silver Image

$D$  = density of the image,  $m_{Ag}$  = grams of silver per dm<sup>2</sup>,  $P$  =  $m_{Ag}/D$  = photometric constant,  $E$  = exposure in mcs. (see "Sensitometric constants" below).

<sup>1</sup> Cf. Vol. VI, section by Conant.

### DENSITY RANGE WITH FERROUS OXALATE DEVELOPMENT; cf. (7, 17, 37)

10 <sup>3</sup> P = .....	1.21	1.31	1.03	1.031	1.19*
D range.....	0.525-1.97	0.76-2.54	0.5-2.0	0.5-3.5	0.08-1.64
Lit.....	(13)	(13)	(7)	(37)	(32)

\* No specific developer mentioned. Scheffers found that quinol, pyrogallol, metol, ferrous oxalate, and glycine gave identical results in his solarization experiments. Scheffers' results indicate that the photometric constant of the developed solarized image progressively diminishes, due to smaller silver grains being formed.

### EFFECT OF EXPOSURE (32)

Log <sub>10</sub> E	D	P	Log <sub>10</sub> E	D	P
5.15	0.08	1.125	0.95	1.52	1.184
4.55	0.16	1.250	0.35	1.64	1.195
3.95	0.34	1.176	0.25	1.55	1.200
3.35	0.54	1.295	0.85	1.50	1.133
2.75	0.86	1.139	1.45	1.35	1.126
2.15	1.01	1.248	2.05	1.23	1.089
1.55	1.34	1.149	2.65	1.12	1.062

Meidinger (27), developing with metol, has found that  $P$  varies with the grain size of the emulsion, a conclusion in accord with Higson (15) and Nutting (29). Meidinger concludes that for a given density, other factors constant,  $P$  is independent of exposure and development time.

### EFFECT OF GRAIN SIZE (27)

E, relative	D, range	$m_{Ag}$ , range	Number of observations	P, average
Fast plate, large grain emulsion				
1-25 600	0.76-2.55	1.45-4.63	11	1.82
Process plate, fairly fine grain emulsion				
1-32	0.26-4.20	0.26-3.8	6	1.0
Transparency plate, very small grain emulsion				
1-512	0.05-3.05	0.04-2.95	10	0.83

The "covering power" of silver grains is proportional to the reciprocal of the photometric constant and increases with decreasing grain size. Thus Meidinger (27) found that the covering powers of a given mass of silver in the developed images of fast, process and transparency plates stood in the ratio 5:9.1:10.5, a conclusion in qualitative agreement with Higson and Toy (16).

## Part II

### Sensitometric Constants of Type Plates and Films

The definition of the sensitometric constants usually employed for expressing the characteristics of photographic materials can best be accomplished by referring to Fig. 1 which shows typical characteristic curves.

**Density ( $D$ ).**—The blackness, or light absorbing power of a photographic deposit is expressed in terms of density defined as follows: Let  $F_0$  = the luminous flux incident upon the deposit;  $F_1$  = the luminous flux transmitted by the deposit;  $O$  = opacity;  $D$  = density;  $T$  = transmission.

Then

$$T = \frac{F_1}{F_0}$$

$$O = \frac{1}{T} = \frac{F_0}{F_1}$$

$$D = \log_{10} O = \log_{10} \frac{1}{T} = \log_{10} \frac{F_0}{F_1}$$

**Exposure ( $E$ ).**— $E = It$  (expressed in meter candle seconds, mcs.);  $I$  = the illumination (in meter candles, mc.) incident on the photographic material during exposure;  $t$  = exposure time (expressed in seconds, s).

**Spectral Composition of Exposing Radiation.**—The values of speed given in the following table were obtained by using a light



source approximately equivalent to noon sunlight in spectral composition. The unit of photographic intensity is defined as one visual candlepower of radiation equivalent in spectral composition to mean noon sunlight.

**Gamma ( $\gamma$ ).**— $\gamma$  = tangent of angle  $\alpha$  which the straight line portion of the characteristic curve makes with the exposure axis.

**Gamma Infinity ( $\gamma_\infty$ ).**— $\gamma_\infty$  is defined as the theoretical limiting value to which  $\gamma$  approaches as the development time is increased. The values of  $\gamma_\infty$  given in the table are computed by the formula (37).

$$\gamma_\infty = \frac{\gamma_1}{1 - e^{-Kt_1}}$$

where  $\gamma_1$  is the slope of the straight portion for the development time  $t_1$ , and  $K$  is the velocity constant of development.

**Velocity Constant of Development ( $K$ ).**— $K = \frac{1}{t} \log_e \frac{\gamma_1}{\gamma_2 - \gamma_1}$ .

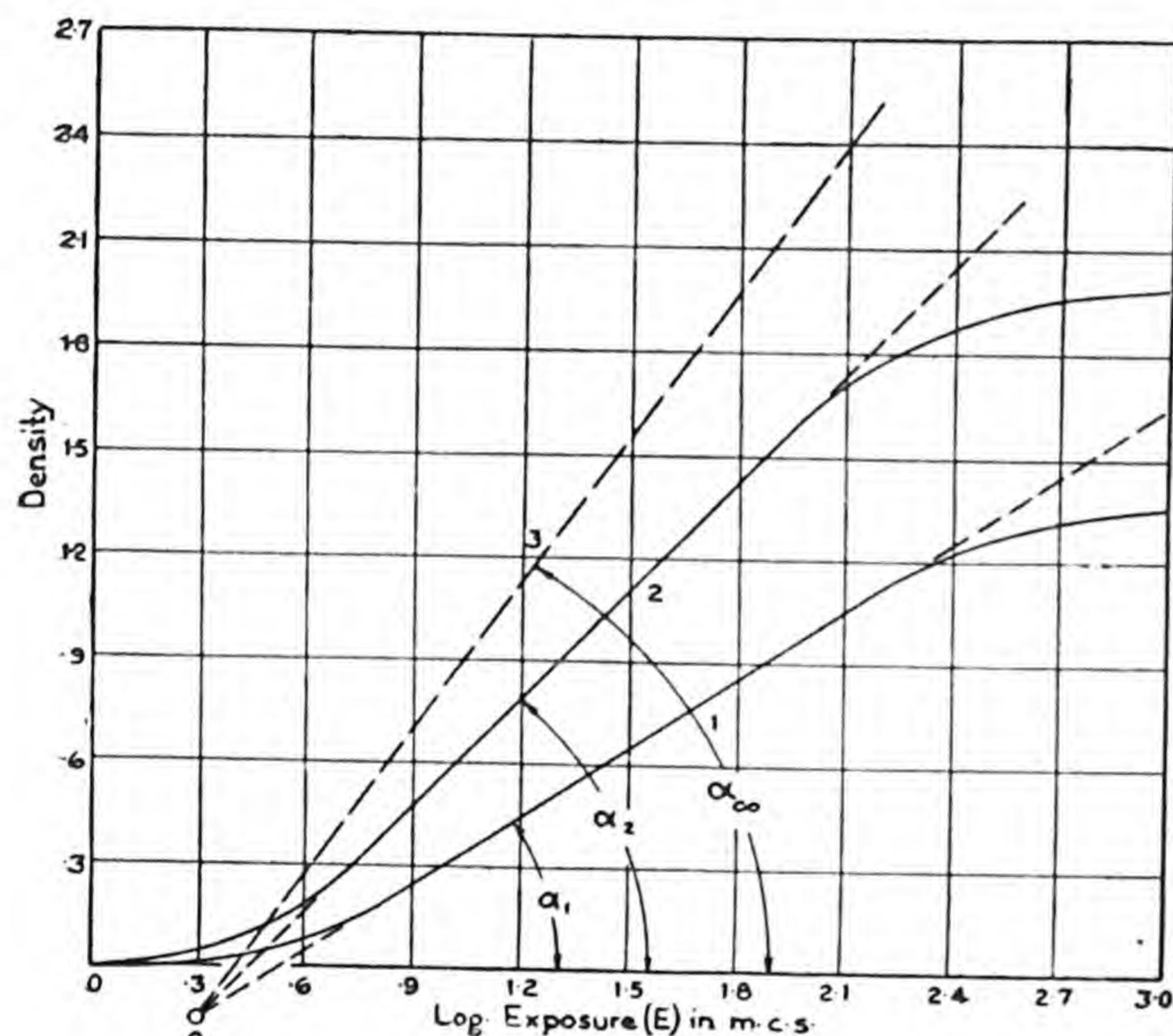


FIG. 1.

**Time of Development for Gamma of Unity ( $t_\gamma = 1.0$ ).**—The rate of development for practical purposes may be indicated by the time of development required to give a gamma of unity. The values determined experimentally for the various type plates and with the developer made up according to the appended formula are given in the table of constants.

**Fog ( $F$ ).**—Fog is defined as the density produced when the plate is developed without exposure. This value naturally depends upon the extent to which development is carried and the values given in the table are for a development time which would result in a gamma of unity.

**Latitude ( $L$ ).**— $L$  = length of the projection (expressed in exposure units) of the straight line portion on the  $\log_{10} E$  axis, assuming development to a gamma of unity.

**Inertia ( $i$ ).**— $i$  = the value of exposure where the straight line portion of the characteristic curve extended cuts the  $\log_{10} E$  axis. The straight line portions of curves plotted for different development times in general intersect in a point  $O$  which may lie above, on, or below the  $\log_{10}$  exposure axis. The value of  $i$ , therefore may depend upon the extent to which development is carried. The values of  $i$  given in the table were determined for a gamma of unity.

<sup>1</sup> Sometimes called Scale, see (5).

**Speed ( $S$ ).**— $S = \frac{1}{i} \times 10$ . Values in table do not include the factor of 10.

#### SENSITOMETRIC CONSTANTS FOR TYPE PHOTOGRAPHIC MATERIALS

Material	Fog $\gamma = 1$	$K$	$\gamma_\infty$	$t$ (for $\gamma = 1.00$ )	$L$	$i$
1. Cine, Extra Fast.....	0.20	0.10	1.4	8.5	100	0.0083
2. Cine, Normal.....	0.15	0.14	1.3	8.5	64	0.014
3. Cine, Panchromatic...	0.15	0.15	2.0	3.5	50	0.025
4. Cine, Positive.....	0.03	0.23	2.7	1.2	32	0.500
5. Portrait, Extra Fast...	0.18	0.10	1.4	8.5	100	0.0083
6. Portrait, Normal.....	0.15	0.10	1.8	5.0	64	0.0166
7. Amateur Film.....	0.15	0.10	1.8	5.0	32	0.022
8. "Focal Plane" Plates..	0.15	0.10	1.7	6.0	64	0.010
9. Commercial, Ordinary.	0.05	0.10	2.2	3.0	32	0.050
10. Commercial, Ortho- chromatic.....	0.12	0.14	2.2	4.0	50	0.033
11. Commercial, Panchro- matic.....	0.15	0.15	2.3	3.5	32	0.050
12. Process, Ordinary.....	0.03	0.18	3.0	1.5	16	0.250
13. Process, Panchromatic.	0.10	0.12	3.0	2.0	16	0.143
14. Lantern Slide Plate...	0.03	0.22	3.0	1.2	16	0.500

#### FORMULA FOR LABORATORY PYROGALLOL DEVELOPER

Solution A	g	Solution B	g
$\text{Na}_2\text{SO}_3$ .....	70	$\text{Na}_2\text{CO}_3$ , anhyd.....	75
$\text{NaHSO}_3$ .....	17	$\text{KBr}$ .....	1
Pyrogallol.....	20	Water to 1 liter	
Water to 1 liter			

Temperature 20°C. For use, mix equal volumes of A and B.

#### Spectral Sensitivity of Photographic Materials

The spectral distribution of sensitivity for practical purposes is shown qualitatively by means of wedge spectrograms. These are made by the use of a spectrograph over the slit of which is mounted a wedge of neutral gray glass, the transmission of which decreases logarithmically from the thin to the thick end. The wedge constant was 0.75/mm. In this way the exposure incident on the photographic material for any particular wave-length decreases logarithmically in a direction parallel to the slit of the instrument. When such an exposure is developed the silver deposit on the plate outlines approximately a curve which is the resultant of the *spectral sensitivity* function of the material and the *spectral distribution of energy* in the radiation emitted by the source used for illuminating the slit of the instrument.

The source used in making the spectrograms (Figs. 2 and 3) was the acetylene flame which operates at the color temperature of 2360°K. All plates were given the same exposure. Since the same source was used in all cases, the curves as outlined by the light areas show the *relative spectral sensitivity* of the various materials. By the application of a correction based upon the spectral distribution of energy radiated by a black-body at 2360°K, an approximation to the actual spectral sensitivity of these materials may be obtained. The neutral glass wedge used over the slit of the instrument while fairly non-selective in absorption for radiation of wave-lengths longer than 450  $m\mu$ , increases in density for radiation of wave-lengths shorter than 450  $m\mu$ . The apparent falling off in sensitivity in the region of wave-lengths shorter than 450  $m\mu$  is therefore due to excessive absorption of the neutral wedge rather than to a decrease in the spectral sensitivity of the material (26, 39).

#### Resolving Power, Sharpness, and Astro Gamma

##### Resolving Power

The capacity of the photographic plate or film to render fine detail is usually referred to as its resolving power ( $R$ ). Resolving power is usually determined by photographing on the material a



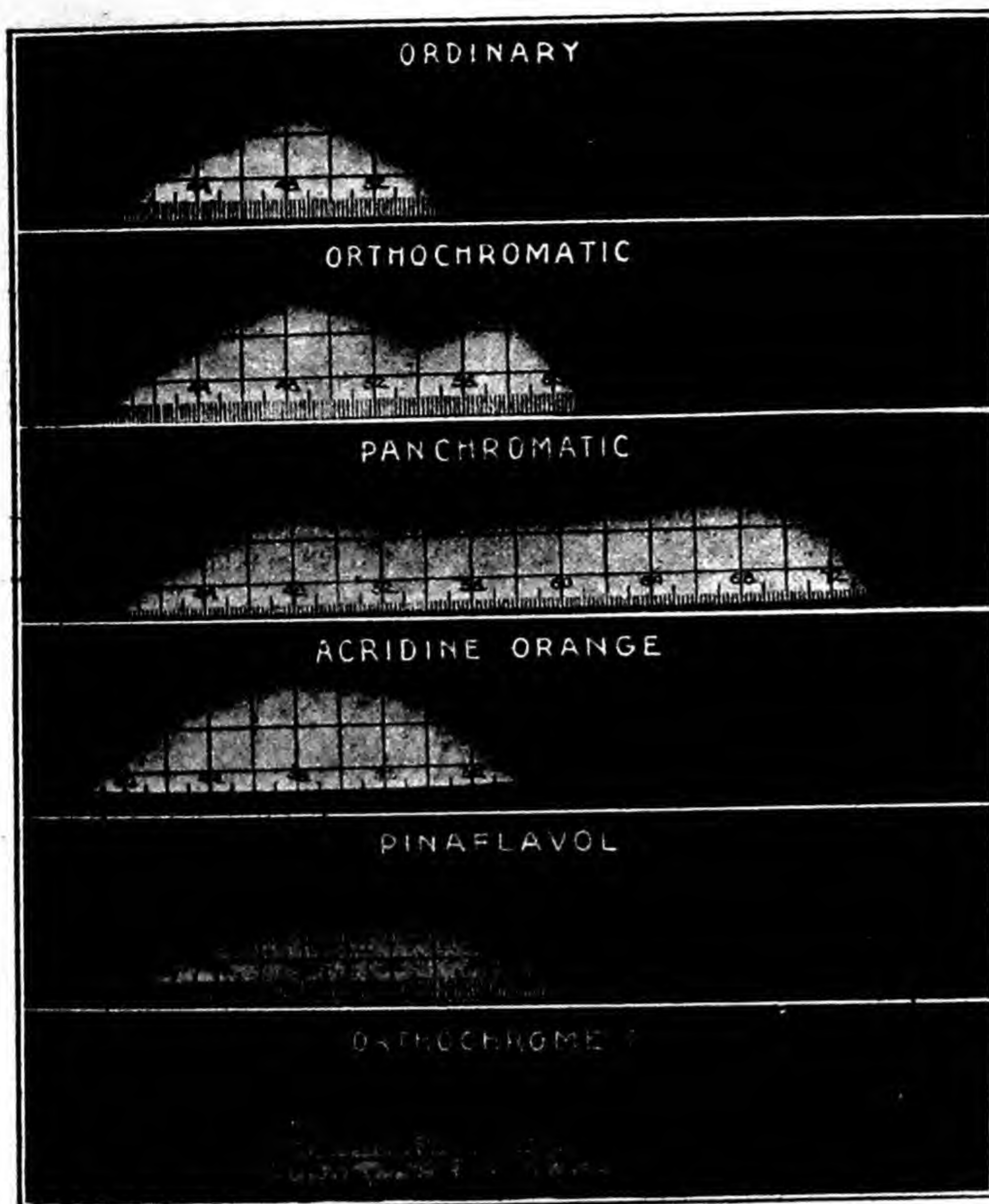


FIG. 2.

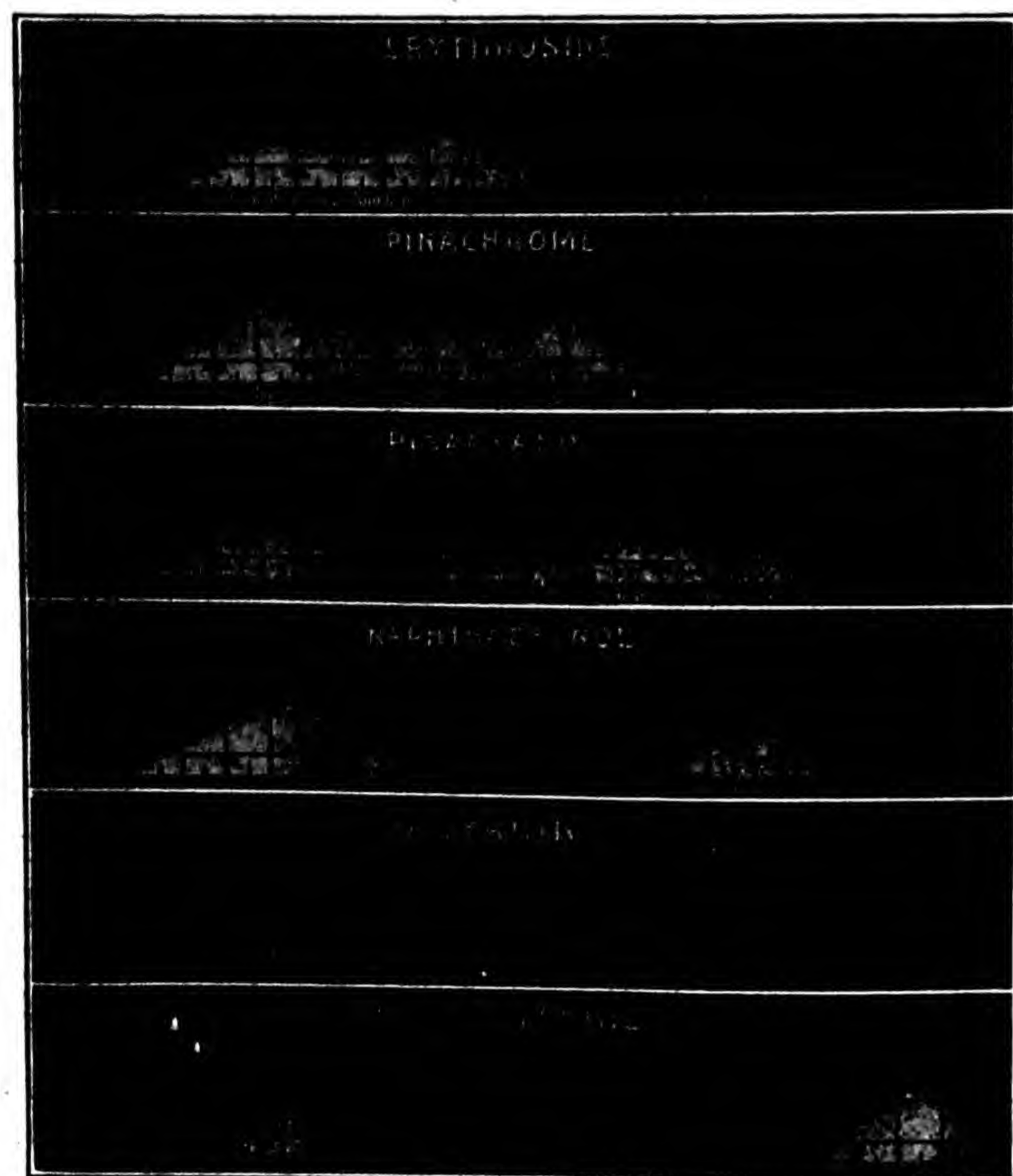


FIG. 3.

grating consisting of alternate light and dark lines, each line being of a width equivalent to the space between the consecutive lines. Resolving power is then specified by stating the number of lines per mm resolvable by the material. For detailed descriptions of methods, *v.* (25, 31).

In Table 1 are given the values of resolving power, as determined by the fan method (25), for a group of materials differing widely in sensitivity. Pyrogallol developer was used in all cases with the exception of the albumen plate, which was developed physically. The light source used in making the exposure was a gas-filled tungsten lamp operated at approximately 2800°K.

TABLE 1 (19)

Plate	Relative speed	Resolving power
Albumen.....	0.01	125
W and W Resolution.....	3.0	81
W and W Slow Process Pan.....	5.0	67
Seed Lantern (yellow label).....	6.0	62
Positive Motion Picture Film.....	10.0	42
Seed 23.....	150.0	35
W and W Panchromatic.....	200.0	31
Seed 30.....	400.0	29
Seed Graflex.....	450.0	25

The resolving power of a photographic plate is dependent to a certain extent upon the reducing agent used in the developing solution. It is also dependent to a certain extent upon the length of time of development and upon exposure. For any given photographic material and developing solution there is a combination of development time and exposure which gives a maximum resolving power. Values of maximum resolving power, as determined by the fan method (25), for various developers are given in Table 2, the light source being a gas-filled tungsten lamp operated at 2800°K.

TABLE 2 (19)

Developer	Maximum resolving power	Exposure (in sec)	Development (in min)
Pyrogallol, NaOH.....	77.0	4	2
Glycine.....	69.0	3	1
Quinol.....	64.0	3	2
Pyrogallol, Na <sub>2</sub> CO <sub>3</sub> .....	64.0	3	2
Metol-quinol.....	64.0	3	2
Metol.....	63.0	3	2
Nepera.....	62.0	3	2
Pyrocatechol.....	62.0	8	2
Pyro-metol.....	62.0	8	2
Eikonogen-quinol.....	61.0	4	3
Ferrous oxalate.....	61.0	2	4
Caustic quinol.....	57.0	4	2
Eikonogen.....	57.0	4	4
Amidol.....	51.0	2	4
Kachin.....	54.0	2	5
Ortol.....	49.0	4	2
p-Aminophenol.....	49.0	8	2
Edinol.....	47.0	4	16

Curves showing the relation between *wave-length* and *resolving power* (fan method) for Seed 30 (S30), Seed 23 (S23), Seed Process (SP), and Wratten and Wainwright Process Panchromatic (WWPP) are shown in Fig. 4 (30, 31).

The increase in resolving power resulting from bathing the material in a solution of yellow dye prior to exposure is shown by the curves marked (YD). The ordinate values are in lines per mm (fan method) which can be resolved under the conditions specified.

Values of resolving power determined by using series of parallel lines may be more directly applicable for practical purposes



especially from the standpoint of spectroscopy. In Table 4 (6) are given values determined in this way for a series of typical photographic materials. The test object was illuminated by light of daylight quality. An image, at a magnification of 0.05, was projected on the surface of the photographic material by means of a highly corrected lens. The exposures were such that a development to gamma of unity in pyrogallol at 20°C gave the maximum resolving power.

Sharpness

The "sharpness" characteristic of a photographic material is defined as the differential of density (*D*) with respect to distance (*s*) in a direction perpendicular to the edge of the image; sharpness (*S*) =  $dD/ds$ , where *s* is expressed in microns (0.001 mm).

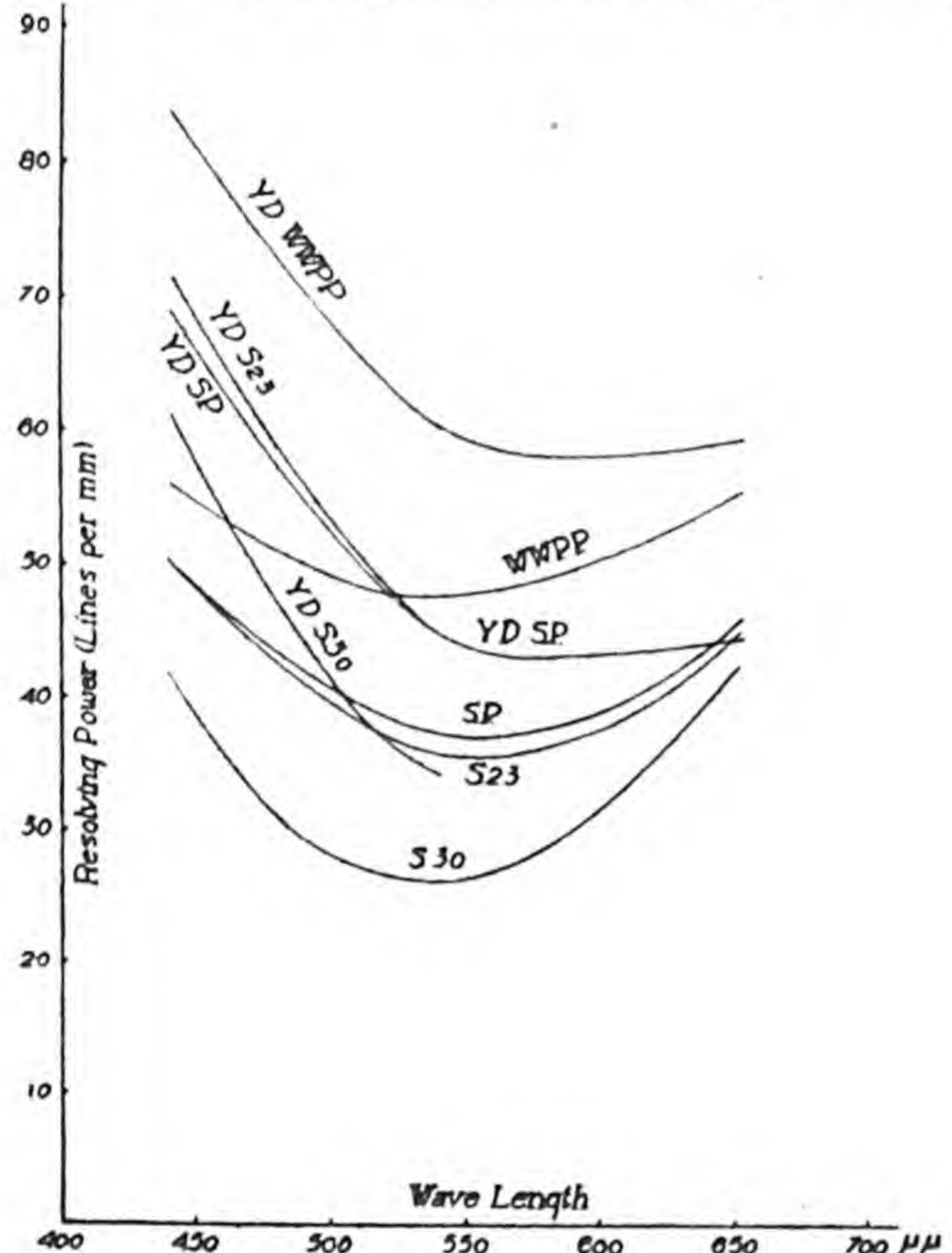


FIG. 4.

The images used for determination of sharpness are obtained by making a contact print of a very carefully prepared knife edge. The exposing radiation used in making the print is carefully collimated and incident normal to the surface of the material being examined.

The sharpness of the developed image depends upon the extent to which development is carried and this is specified by the value of gamma ( $\gamma$ ),  $\frac{dD}{d \log_{10} E}$ .

The curves of Fig. 5 (30, 31) show the relation between sharpness and gamma for various developers. The plate used in obtaining these values was a Seed Panchromatic and the exposing radiation was monochromatic of wave-length 440m $\mu$ .

Sharpness is independent of exposure, at least over a considerable range, as shown in Table 3. The term "light exposure" is used to designate an exposure resulting in an image density of approximately 1.0, while the term "heavy exposure" is used to designate an exposure resulting in an image density between 2.0 and 3.0. The plate used was a Seed Panchromatic developed in caustic hydroquinol.

TABLE 3.—DENSITY GRADIENTS

	$\lambda = 420m\mu$			$\lambda = 520m\mu$			$\lambda = 660m\mu$		
Development time, min.	0.75	1.5	3.0	0.75	1.5	3.0	0.75	1.5	3.0
For light exposure...	0.107	0.136	0.143	0.051	0.059	0.069	0.053	0.070	0.082
For heavy exposure...	0.112	0.133	0.151	0.045	0.061	0.063	0.056	0.064	0.086

The relation between sharpness and wave-length of the exposing radiation is shown in Figs. 6 and 7 (30, 31), the former applying to a panchromatic (Seed Panchromatic) and the latter to an orthochromatic (Standard Orthonon) material.

Values of sharpness for a group of typical materials are given in Table 4 (6). The quality of light used in making the exposures was equivalent to average daylight. The exposure was so adjusted that development to gamma of unity in pyrogallol at

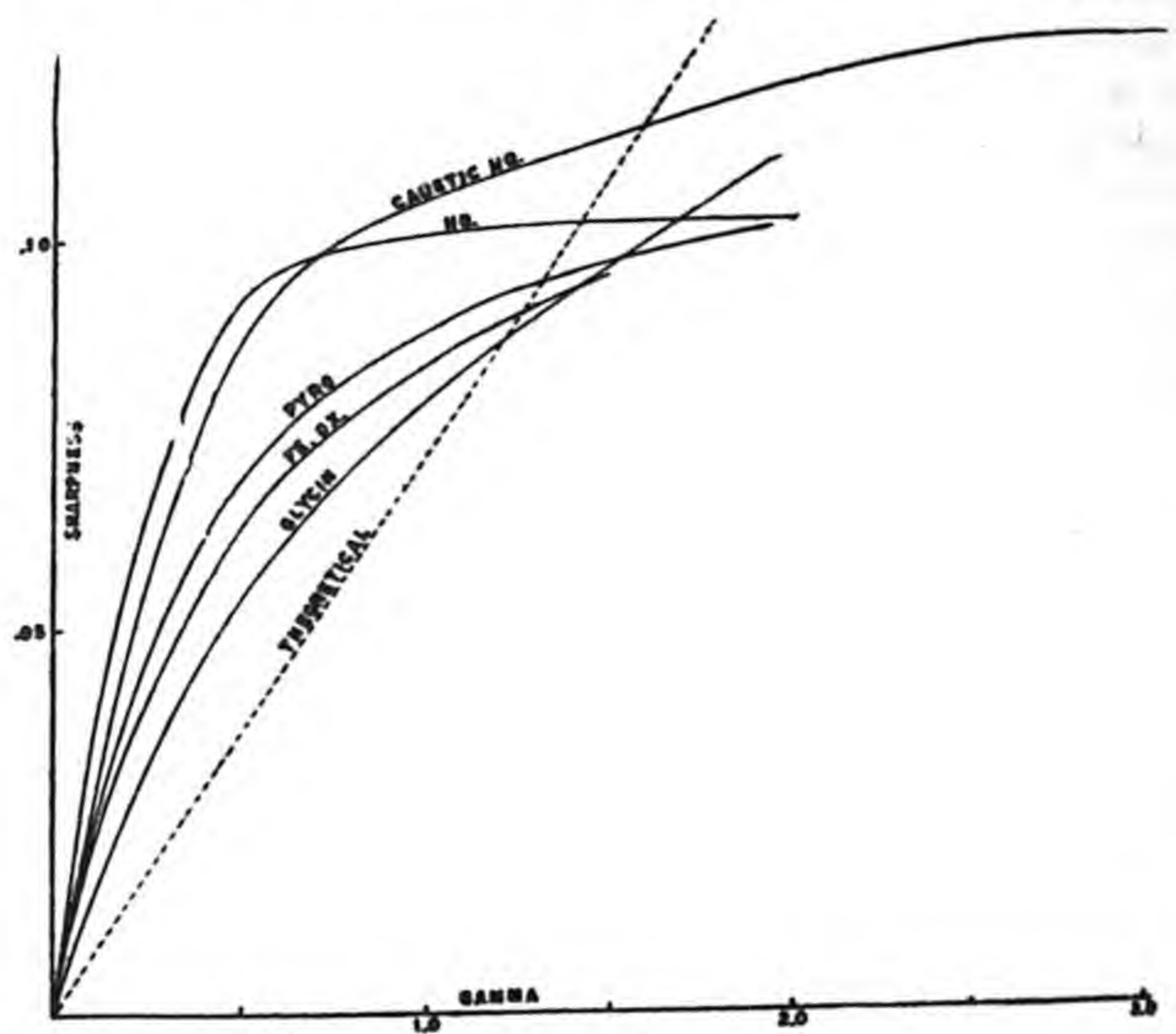


FIG. 5.

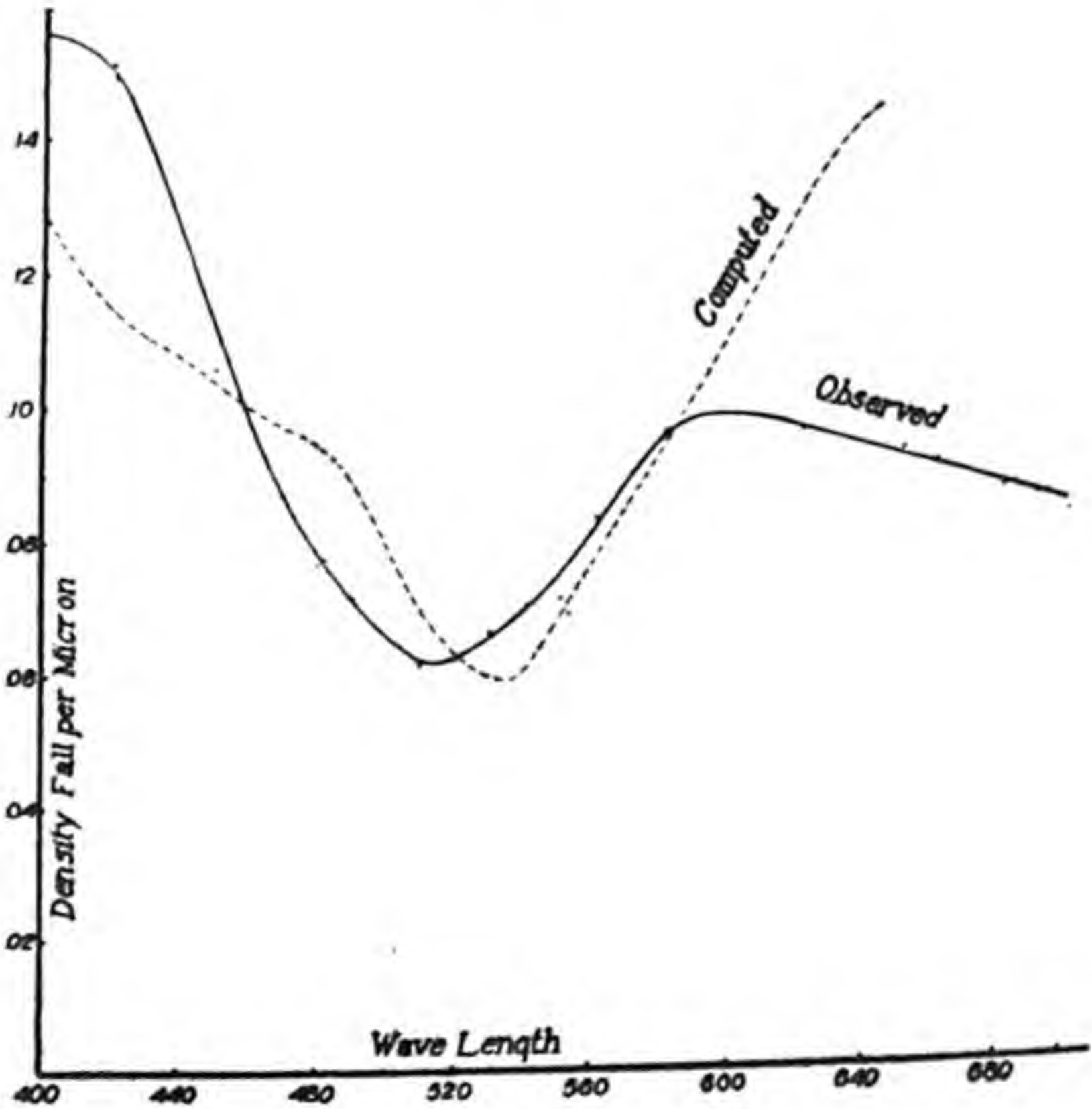


FIG. 6.

20°C gave an image density of unity. The values of sharpness express the diffuse-density gradient ( $dD/ds$ ) of the straight line portion of the sharpness curve obtained by plotting diffuse-density (*D*) as a function of the distance (*s*) from the geometrical edge of the image.

Astro Gamma

Astro gamma is defined as the coefficient (*b*) of  $\log_{10} E$  in the Scheiner equation, which gives the relation between the diameter (*D*) of a stellar image and the exposure (*E*):  $D = a + b \log_{10} E$ .



Since exposure ( $E$ ) = intensity ( $I$ )  $\times$  time ( $t$ ) this equation offers a means of determining the relative brightness of stars by measurement of the diameter of the stellar images obtained under known conditions of exposure and development. The ordinate values used in plotting Fig. 8 are relative and must be multiplied by 3.33 ( $1/\log_{10} 2$ ) in order to obtain actual values of astro gamma as defined above.

In Table 4 (6) are given values of astro gamma for a group of typical photographic materials. These values were determined by photographing with a highly corrected lens, using a magnification of 0.05, a circular aperture having a diameter of 0.56 mm. Exposing radiation was of daylight quality and intensity was so adjusted that an exposure of 1 second was just above the threshold value. Keeping the intensity factor constant, the exposure time was increased by consecutive powers of 2 from 1 to 512 seconds. The exposed plates were developed to a gamma of unity in standard pyrogallol at 20°C.

TABLE 4

Emulsion	Resolving power	Sharpness	Astro gamma
Eastman Lantern.....	140	0.168	39*
Eastman Process.....	140	0.156	30*
Eastman Cine Positive.....	120	0.103	26*
W and W Process Panchromatic....	102	0.092	33
Eastman 33.....	95	0.088	32
Eastman D. C. Ortho.....	80	0.097	41
Eastman Universal.....	70	0.093	40
Eastman 40.....	70	0.071	49*
Eastman Speedway.....	60	0.080	44
Eastman Cine, Par Speed.....	60	0.085	35
Eastman Cine Superspeed.....	50	0.080	36
Eastman Superspeed Portrait.....	50	0.065	43

\* The growth of the diameter with the log exposure deviates much from a linear relationship. The value given is the average of the values over the whole range of exposures.

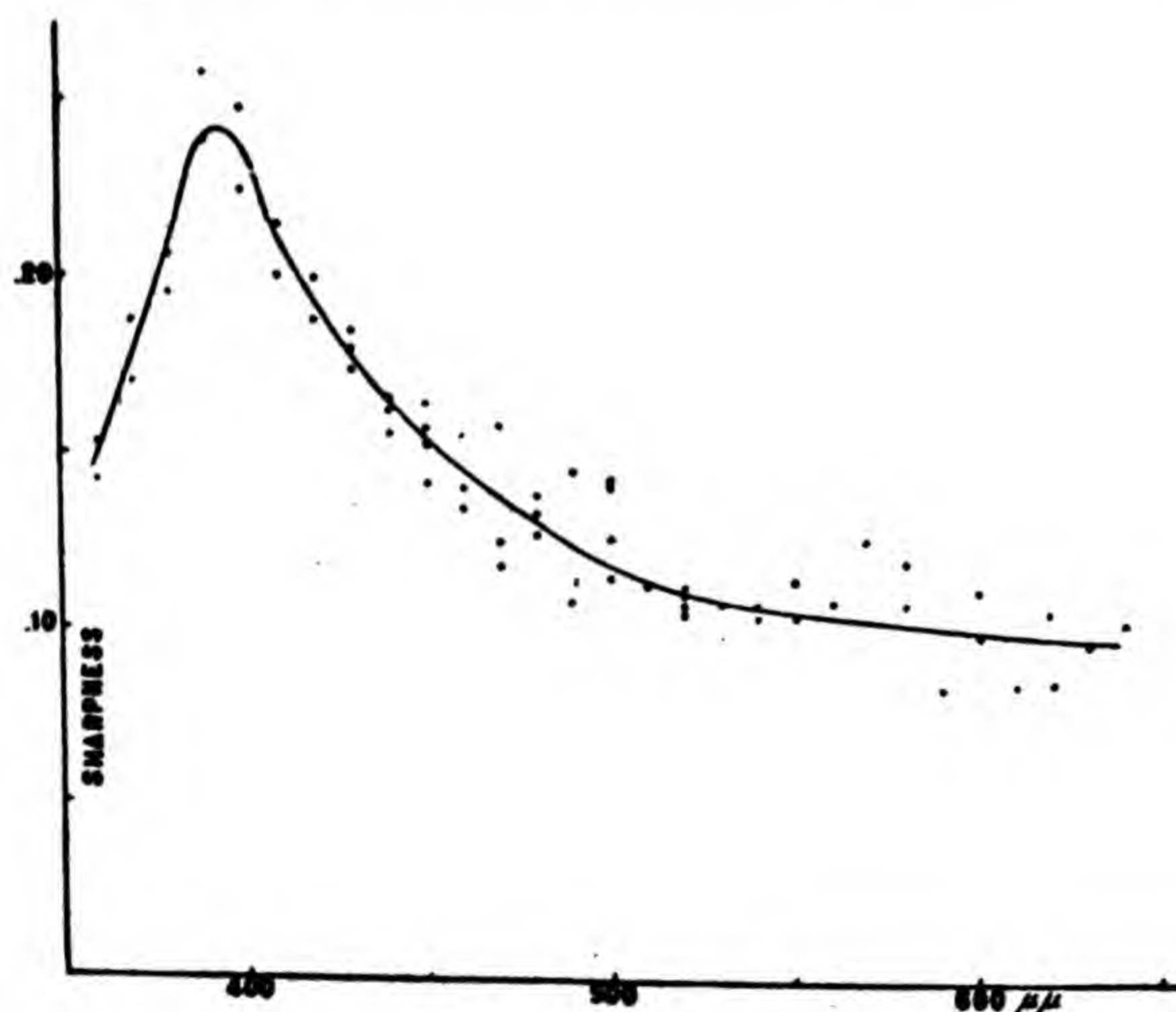


FIG. 7.

#### Relative Photographic Efficiency of Illuminants (23)

$C$  = luminous efficiency of source (lumen/watt).  $E_r$  = relative photographic efficiency of source evaluated on basis of equal visual intensities, sunlight = 100%.  $E_s$  = relative photographic efficiency of source evaluated on basis of equal energy consumption by the source, sunlight = 100%.

#### Efficiency of Illuminants.—(Continued)

Source	$C$	Photographic material				Panchromatic	
		Ordinary		Orthochromatic		$E_r$	$E_s$
		$E_r$	$E_s$	$E_r$	$E_s$		
Sun.....	150	100	100	100	100	100	100
Sky.....		181		155		130	
Acetylene.....	0.7	30	0.14	44	0.21	52	0.24
Acetylene (screened)*.....	0.07	81	0.037	85	0.040	89	0.042
Pentane.....	0.45	18	0.053	28	0.086	42	0.13
Mercury arc in quartz.....	40.0	600	158	500	132	367	99
Mercury arc in nutra glass.....	35.0	218	50	195	46	165	39
Mercury arc in crown glass.....	37.0	324	79	275	68	249	62
Carbon arc, ordinary.....	12.0	126	10	112	9	104	8.5
Carbon arc, white flame.....	29.0	257	52	234	45	215	4.2
Carbon arc, enclosed.....	9.0	175	11	177	11	165	10
Carbon arc, "Aristo".....	12.0	796	62	1070	86	744	60
Magnetite arc.....	18.0	106	12	115	14	82	10
Carbon glow lamp.....	2.4	23	0.37	32	0.52	42	0.68
Carbon glow lamp.....	3.2	25	0.51	35	0.74	45	0.95
Tungsten (vacuum).....	8.0	33	1.7	41	2.2	50	2.7
Tungsten (vacuum).....	9.9	37	2.4	45	3.0	53	3.5
Tungsten (gas filled).....	16.6	56	6.1	62	6.8	70	7.7
Tungsten (gas filled).....	21.6	64	8.9	68	9.8	76	11.0
Tungsten (C <sub>1</sub> ).....	8.9	95	5.5	87	5.2	95	5.6
Tungsten (C <sub>2</sub> ).....	11.0	108	7.8	99	7.3	106	7.9
Mercury vapor.....	23.0	316	47	354	54.2	273	42.0

\* Screened with Wratten No. 79 filter.

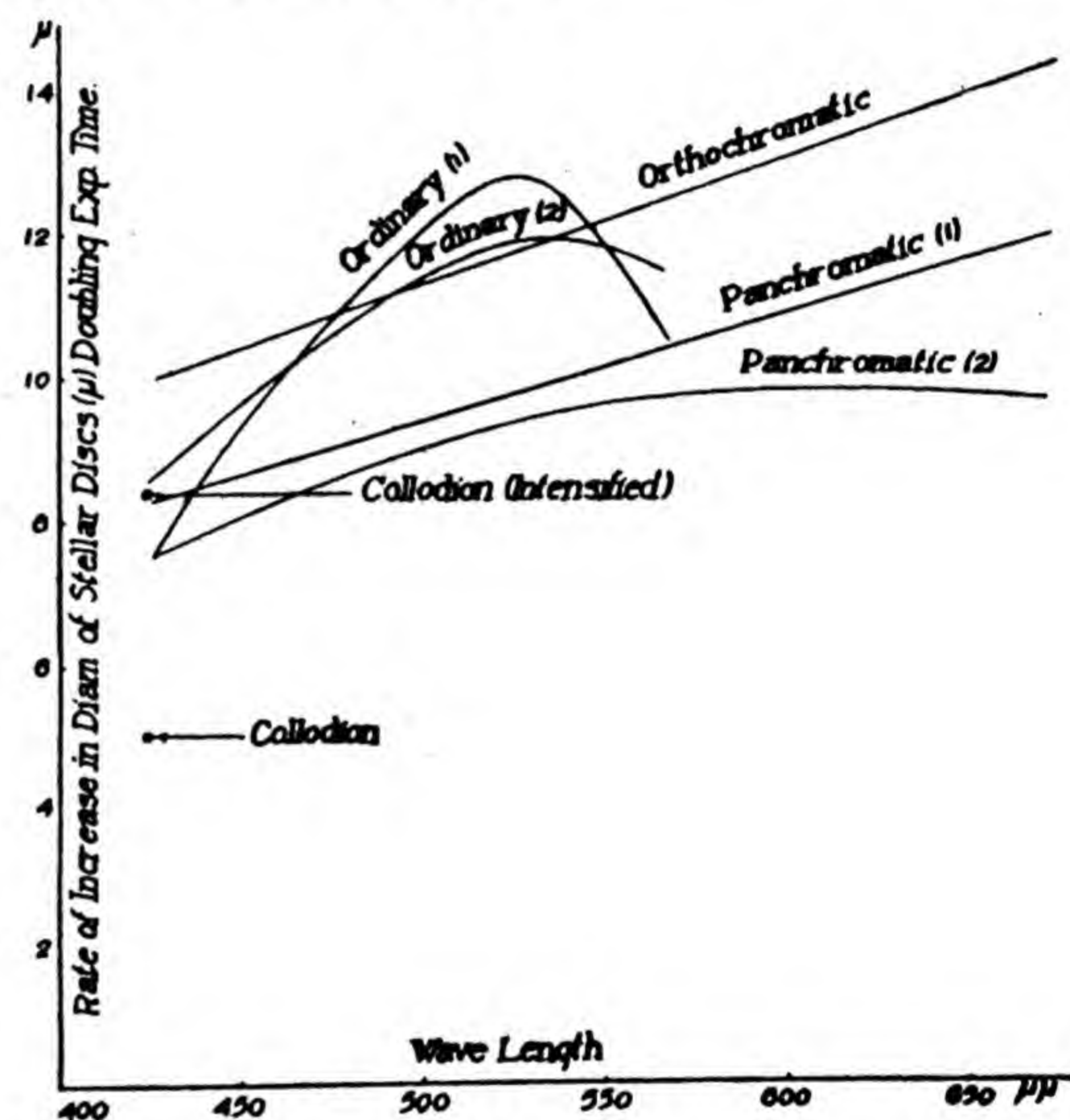


FIG. 8.

#### Gloss of Photographic Papers

**Definition of Gloss.**—With the surface illuminated by a collimated beam of light incident at 25° from the normal to the surface,  $B_s$  is the brightness of the sample as observed on the line of specular reflection (angle of observation equal to angle of incidence) and  $B_d$  is the brightness of the surface observed normally.

Specular brightness, ( $B_s$ ) =  $B_s - B_d$ ; diffuse brightness, ( $B_d$ ) =  $B_d$ ; gloss ( $G$ ) =  $\frac{B_s}{B_d} = \frac{B_s - B_d}{B_d} = \frac{B_s}{B_d} - 1$ .

#### RANGE OF GLOSS VALUES

Matte	Semi-matte	Semi-gloss	Gloss
0-1	1-3	3-7	7-∞*

\* Actual limit = 75.

These values apply to samples which were fixed out without exposure and hence represent the white paper without any developed silver deposit (22).



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(For a key to the periodicals see end of volume)

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## PROPERTIES OF SOAPS AND THEIR AQUEOUS SOLUTIONS

JAMES W. MCBAIN

A soap is here defined as a salt of any monobasic aliphatic acid containing six or more carbon atoms. The substance cetylsulfonic acid is also classed as a soap.

Un savon est défini ici comme étant un sel de tout acide aliphatique monobasique contenant six atomes de carbone ou plus. La substance acide cétylsulfonique est aussi classée comme savon.

Die Seife ist hier definiert als ein Salz irgend einer aliphatischen einbasischen Säure, welche sechs oder mehr Kohlenstoffatome enthält. Der Stoff Cetylsulfonsäure ist als eine Seife klassifiziert.

Si intende qui per sapone il sale di un acido alifatico monobasico qualunque contenente sei o più atomi di carbonio. L'acido cetilsolfonico è considerato anch'esso un sapone.

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Density.

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Phase-rule equilibria.

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Freezing-point lowering.

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Konversions Formeln.

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Phasengleichgewichte.

Löslichkeit.

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## Symbols and Molecular Weights

 $N_w$  (resp.  $N_v$ ) = Gram-moles per kg  $H_2O$  (resp. per l solution), % = weight per cent

Symbol	Name	Mol. wt.	Symbol	Name	Mol. wt.
$NaC_6$	Caproate or hexoate	138.082	$KC_{18}$	Stearate	322.365
$KC_6$		154.180	$NaC_{22}$	Behenate	362.328
$NaC_8$		166.113	$C_{16}SO_3H$	Cetylsulfonic or hexadecanesulfonic acid	306.327
$KC_8$		182.211	$C_{16}SO_3Na$	Cetylsulfonate	328.316
$NaC_9$	Nonylate	180.128	$NaC_{18}^*$	Oleate	304.251
$NaC_{10}$		194.143	$KC_{18}^*$	Oleate	320.349
$KC_{10}$	Caprate or decoate	210.241	$NH_4C_{18}$	Oleate	299.293
$NaC_{12}$		222.174	$NaC_{18}$	Linolate	302.236
$KC_{12}$	Laurate	238.272	$KC_{18}$	Linolate	318.334
$NaC_{14}$	Myristate	250.205	$NaC_{22}$	Erucate	360.313
$KC_{14}$	Myristate	266.303	$KC_{22}$	Erucate	376.411
$NaC_{16}$	Palmitate	278.236	$NaC_{18}$	Linolenate	300.22
$KC_{16}$	Palmitate	294.334	$KC_{18}$	Linolenate	316.318
$NH_4C_{16}$	Palmitate	273.278	$NaC_{18}OH$	Ricinoleate	320.251
$NaC_{18}$	Stearate	306.267	$KC_{18}OH$	Ricinoleate	336.349

\* The symbol  $C_{18}$  is used in the tables for oleates only, the st reoisomeric elaidates being named in full.



## Conversion Formulae

$$\text{Wt. \%} = \frac{\text{Mol. wt.} \times N_w}{\text{Mol. wt.} \times N_w + 1000} \times 100$$

$$N_w = \frac{\text{Wt. \%}}{\text{Mol. wt.}} \times \frac{1000}{100 - \text{Wt. \%}}$$

$$N_w = \frac{\text{Wt. \%} \times \text{density of solution} \times 10}{\text{Mol. wt.}}$$

## Equilibria within Soap Solutions

The diagrams, Figs. 1-19, represent the proportions of the various constituents in equilibrium with each other in the soap solutions. They are obtained primarily from a comparison of conductivity and osmotic data but some of the results are confirmed by measurements of Na and K ion by emf, ultrafiltration, etc. In each concentration the sum total of constituents containing fatty acid radical is taken as 100 % (the total height of the diagram) which is the sum of the following: Colloidal neutral undissociated soap, crystalloidal undissociated soap, fatty ion and fatty ion aggregated as ionic micelle; in addition there is free Na or K ion equal in amount to the number of equivalents of free fatty ion plus the fatty ion in ionic micelle. To read off the actual concentration of any one constituent at a given concentration the width of the field representing that constituent must be multiplied by the total concentration of the solution. The uncertainty in the position of the boundaries between fields is estimated as about 10 % of the total amount of soap. For further description, see (89). Constituents of a soap solution containing added salt (109).

## SYMBOLS

- N Neutral colloid, e.g.,  $(\text{KC}_{18})_x$ .  
 S Simple soap molecules, e.g.,  $\text{KC}_{18}$ .  
 S' Simple fatty ions, e.g.,  $\text{C}_{18}^-$ .  
 A Acid soap.  
 M Ionic micelle, e.g.,  $(\text{C}_{18}^-)_n$ .

## Viscosity

Values of  $\eta$  in poises

SOLUTIONS OF PURE SOAPS. See FIGS. 20, 21, AND 22

Capillary viscometer with absolute dimensions such that kinetic correction did not exceed 1 %. Viscosity compared with that of water at 20° taken as unity (51).

Soap	$N_w$ at 90°	20°	30°	45°	60°	90°
$\text{KC}_{18}$ .....	0.1	1.15		0.671	0.532	0.352
	0.2	1.41	1.13	0.846	0.661	0.434
	0.375	1.96		1.16	0.906	0.604
	0.4	2.08	1.65	1.24	0.962	0.626
	0.6	3.28	2.61	1.97	1.54	1.03
	0.8	4.97	4.01	3.04	2.37	1.55
	1.0	8.42	6.94	5.38	4.24	2.81
$\text{KC}_{14}$ .....	0.054	1.14	0.895	0.672	0.519	0.346
	0.216	1.70	1.32	0.983	0.752	0.497
	0.431	2.83	2.17	1.63	1.25	0.825
	0.649	4.94	3.84	2.87	2.22	1.45
	0.815	9.34	7.67	5.86	4.56	2.85
	1.035	39.1	36.2	28.3	17.7	6.47
	0.052	1.19	0.95	0.709	0.545	0.364
$\text{KC}_{12}$ .....	0.2	1.87	1.47	1.10	0.837	0.500
	0.375	4.19		1.91	1.39	0.919
	0.4	8.02	4.69	3.12	1.99	1.13
	0.6	1573		60.22	18.03	3.80

See further the following references:  $\text{NaC}_{18}$ ,  $\text{KC}_{18}$  (2, 99),  $\text{KC}_{12}$  (11),  $\text{NaC}_{12}$  (99),  $\text{NaC}_{18}$  (99),  $\text{NH}_4\text{C}_{18}$  (2, 33, 34, 35), Na salt of fatty acids from tallow and from coconut oil (99), K and  $\text{NH}_4$  salts of fatty acids from palm kernel oil (27, 28, 51).

VISCOSITY OF SOAP SOLUTIONS WITH ADDITIONS OF OTHER SOLUTES  
Bibliography only

Soap	Addition	Lit.
$\text{KC}_{12}$ .....	KOH	(51)
$\text{KC}_{12}$ .....	$\text{KC}_{18}(\text{I} + \text{KOH})$	(51)
$\text{KC}_{18}$ .....	KOH	(51)
K (palm)*.....	KOH	(27)
	KCl	
K (palm)*.....	Glycerol	(28)
	Acetone	
K (palm)*.....	$\text{K}_2\text{CO}_3$	(51)
	KOH	
K (coco)†.....	KCl	(56)
	$\text{KC}_{18}$	
$\text{NaC}_{12}$ .....	NaOH	(108)
$\text{NaC}_{18}$ .....	NaCl	(44, 91)
	$\text{Na}_2\text{CO}_3$	
	$\text{NaC}_2\text{H}_3\text{O}_2$	(22)
	NaOH	
	NaCl	(22)
	KCl	
$\text{NH}_4$ (palm)*.....	$\text{NH}_3$	(28)
	$\text{NH}_4\text{Cl}$	
	Both	

\* Palm kernel oil acids. † Coconut oil acids.

## Density (Specific Gravity)

$$d_4^t = A + kN_w; \text{VALUES OF } d_4^t; A = 0.9986 = d_4^{18} \text{ of H}_2\text{O}$$

Soap	0.05 $N_w$	0.1 $N_w$	0.2 $N_w$	0.5 $N_w$	1.0 $N_w$	k	Lit.
$\text{NaC}_8$ *.....	1.003	1.004	1.008	1.016	1.030	†	(54)
$\text{NaC}_{12}$ *.....	1.001	1.002	1.004			†	(54)
$\text{NaC}_{18}$ .....	0.9990	0.9995	1.0005	1.0035		+0.0098	(53, 77)
$\text{KC}_{18}$ .....	0.9992	0.9998	1.0010	1.0047		+0.0122	(77)
K elaidate..	0.9990	0.9994	1.0001	1.0024		+0.0076	(90)
$\text{NaC}_{18}^{---}$ .....	0.9993	1.0001	1.0016	1.0060		+0.0148	(84)
$\text{NaC}_{18}\text{OH}$ ..	1.000	1.0013	1.0038	1.0097	1.017	†	(71)

\* Volume normality ( $N_w$ ) and  $d_4^{18}$ . † Not linear.

VALUES OF  $d_4^{20}$ ; A = 0.9653 =  $d_4^{20}$  of  $\text{H}_2\text{O}$ 

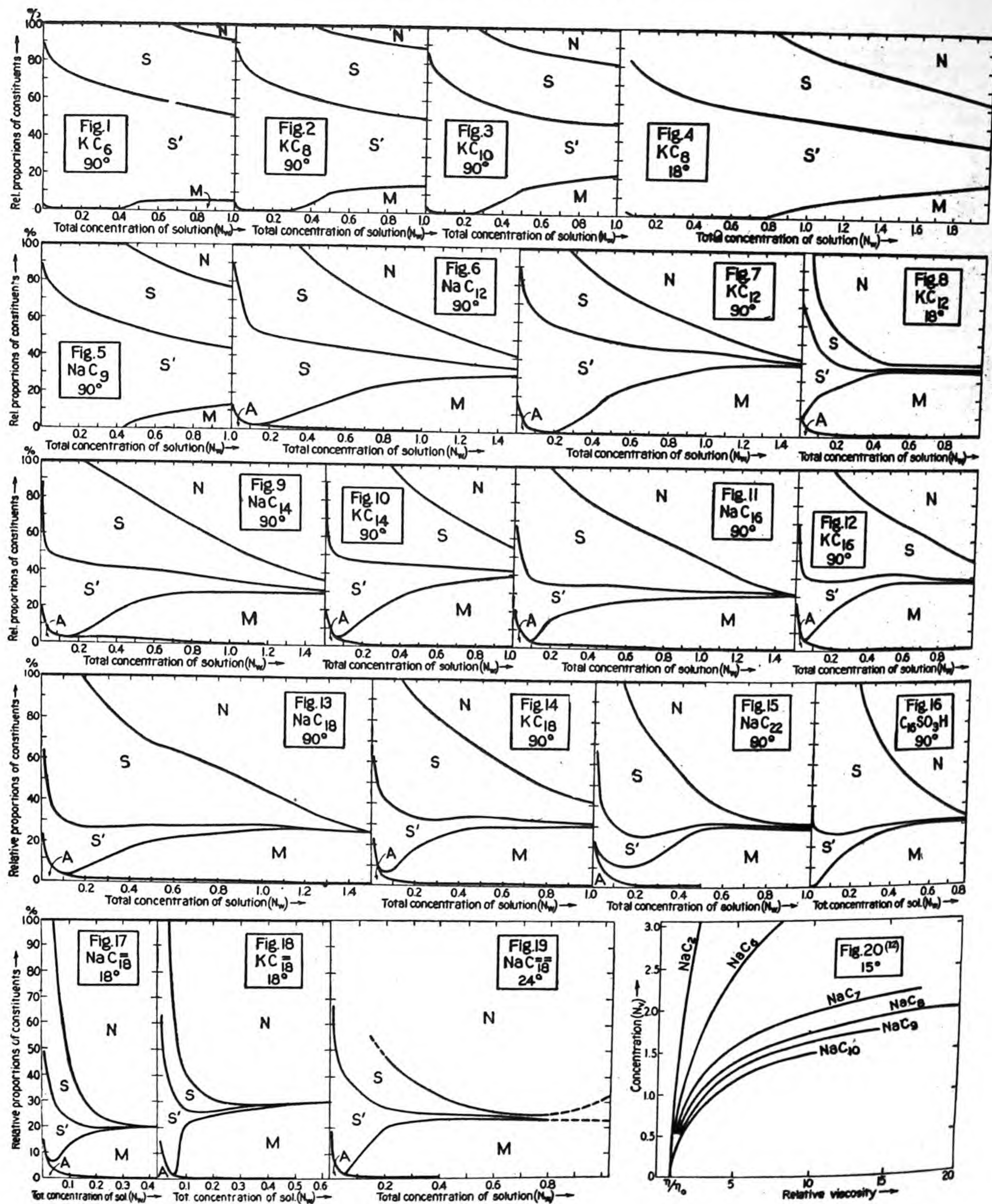
Soap	0.2 $N_w$	0.5 $N_w$	1.0 $N_w$	k	Lit.
$\text{KC}_8$ .....	0.972	0.982	0.998	+0.033	(16)
$\text{KC}_8$ .....	0.9702	0.9777	0.9902	+0.0249	(16)
$\text{NaC}_8$ .....	0.9690	0.9744	0.9833	+0.0180	(26)
$\text{KC}_{10}$ .....	0.9689	0.9743	0.9833	+0.0180	(16)
$\text{NaC}_{12}$ .....	0.9668	0.9692	0.9731	+0.0029	(70)
$\text{KC}_{12}$ .....	0.9676	0.9712	0.9770	+0.0117	(16)
$\text{NaC}_{14}$ .....	0.9658	0.9665	0.9678	-0.0025	(70)
$\text{KC}_{14}$ .....	0.9667	0.9688	0.9723	+0.0070	(16)
$\text{NaC}_{16}$ .....	0.9647	0.9639	0.9624	-0.0029	(18)
$\text{KC}_{16}$ .....	0.9659	0.9667	0.9680	+0.0027	(16)
$\text{NaC}_{18}$ .....	0.9631	0.9599		-0.0108	(18)
$\text{KC}_{18}$ .....	0.9650	0.9645	0.9637	-0.0016	(16)
$\text{NaC}_{22}$ .....	0.96312	0.96		-0.011	(26)
$\text{C}_{18}\text{SO}_3\text{H}$ .....	0.9637	0.9613		-0.0080	(100)

For the K salt of palm-kernel oil (also with added KOH) at 20°, 60°, and 90°, v. (27). For the  $\text{NH}_4$  salt of palm-kernel oil at 20°, 45°, and 60°, v. (28).

VALUES OF  $d_4^t$  FOR 0.1 $N_w$  SOLUTIONS (3)

	35°	45°	55°	65°	75°	85°
$\text{NaC}_{18}$ .....			0.986	0.981	0.974	0.968
$\text{KC}_{18}$ .....	0.994	0.991	0.987	0.982	0.975	0.969







VALUES OF  $d_4^t$  FOR  $\text{NaC}_{18}$   
For the anhydrous soap,  $d_4^{20} = 0.821$  (101)

$N_w$	$t, ^\circ\text{C}$	16 (54)	20 (32)	$N_w$	$t, ^\circ\text{C}$	0 (53)	10 (53)
0.005		1.001*	0.9983	0.2		1.0012	1.0005
0.01		1.001*	0.9984	0.4		1.0040	1.0029
0.1		1.003*	0.9989	0.6		1.0068	1.0062
0.2		1.004*					

\*  $d_{15}^{15}$ .

VALUES OF  $d_4^t$

$N_w =$	0.0001	0.001	0.01	0.05	Lit.
$\text{NaC}_6, d_{15}^{15}$	0.9991	0.9991	1.001	1.003	(54)
$\text{NaC}_9, 20^\circ$	0.9484	0.9985	0.9986		(30)
$\text{NaC}_{12}, 25^\circ$			0.9973	0.9985	(70)
$\text{NaC}_{18}, 23.8^\circ$	0.9973	0.9973	0.9974	0.9977	(66)

$N_w =$	0.1	0.5	0.75	1.0	1.5	Lit.
$\text{NaC}_6, d_{15}^{15}$	1.004	1.020	1.031	1.040	1.057	(54)
$\text{NaC}_{18}, 23.8^\circ$	0.9981	1.0011	1.003	1.005		(66)

\* Concentrations are weight-normal ( $N_w$ ).

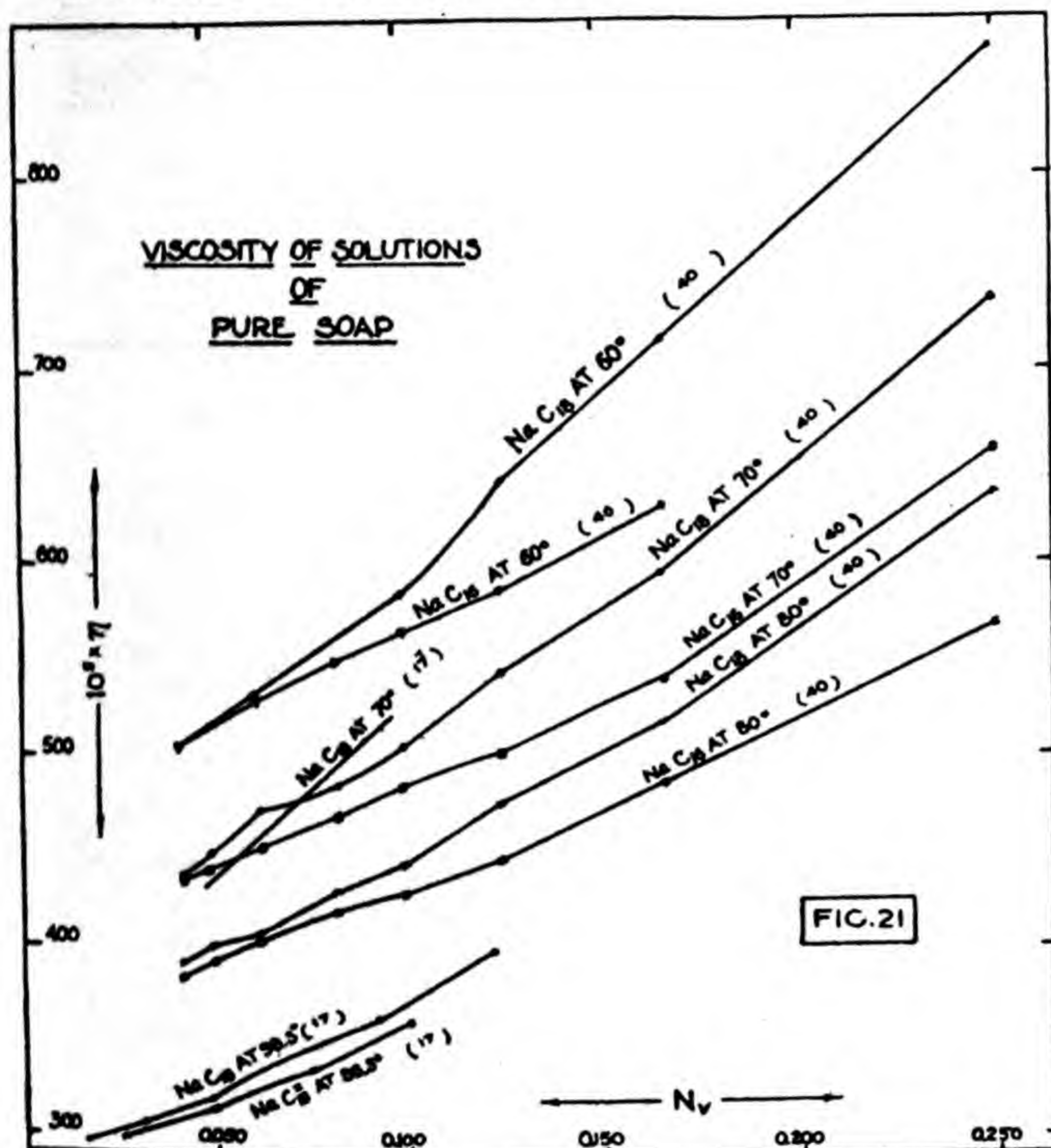


FIG. 21

#### SOLUTIONS OF SOAPS WITH ADDITIONS OF ALKALI, FATTY ACID AND SALTS

$\text{NaC}_6$  (30);  $\text{NaC}_{12}$  (70);  $\text{KC}_x, x = 6, 8, 10, 12, 14, 16, 18$  (16);  $\text{KC}_{12}$  (109);  $\text{NaC}_{14}$  (18, 44, 89, 91);  $\text{NaC}_{18}$  (32).

#### Surface Tension

##### INTERFACE AIR-AQUEOUS SOLUTION

Sodium oleate has been by far the most frequently and carefully measured, but rarely are the effects of age of solution and of age of surface mentioned. For the effect of the latter,  $v$ . (42). Values of  $\gamma$  in dyne/cm for aqueous solutions of various soaps are shown in Figs. 23, 24 and 25. For mixtures of soaps in water at  $60^\circ\text{C}$ ,  $v$ . (126).

Additional Lit.:  $\text{NaC}_{18}$  (7, 10, 31, 42, 63, 94, 95, 96, 97, 101, 102, 110, 111, 126, 129);  $\text{NaC}_{10}$  (127);  $\text{NaC}_{12}$  (8, 127);  $\text{NaC}_6$  (30);  $\text{KC}_{12}$  (8, 11);  $\text{NaC}_{10}$  (12);  $\text{MgC}_{12}$  (31).

#### LIQUID-LIQUID INTERFACE

See (19, 31, 32, 43, 63, 103, 113, 114, 117) and Vol. IV, p. 438.

In no case have the compositions of both phases been completely determined and all factors controlled. For example, interfacial tension of benzene against aqueous solutions of  $\text{NaC}_{18}$  at  $20^\circ\text{C}$  (32):

$10^3 N_w$	0.0	0.1	0.25	0.5	1.0	2.5	5.0	10.0	100
$\gamma$	35.0	32.6	22.6	19.5	10.8	5.37	2.76	2.29	1.46

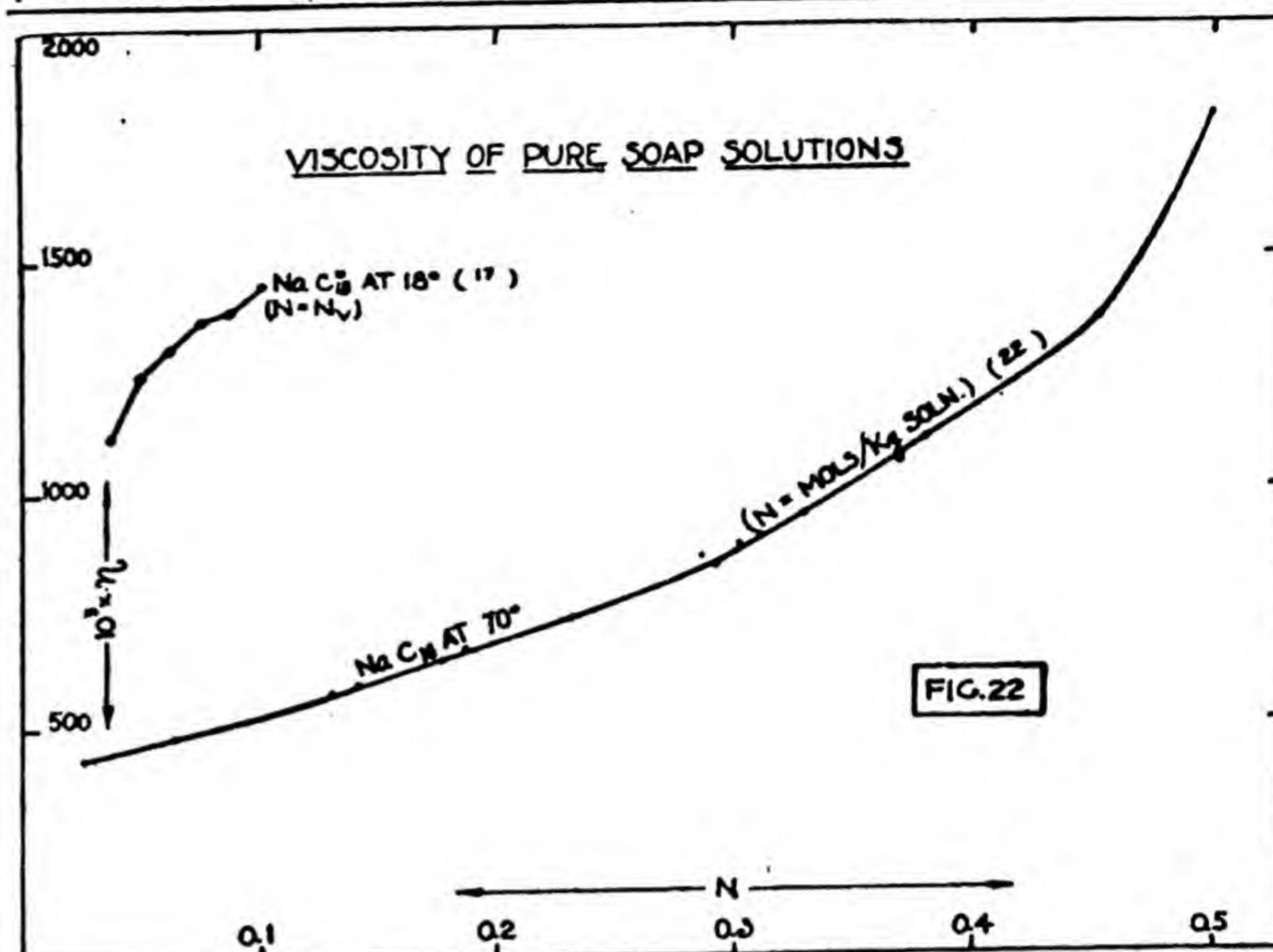


FIG. 22

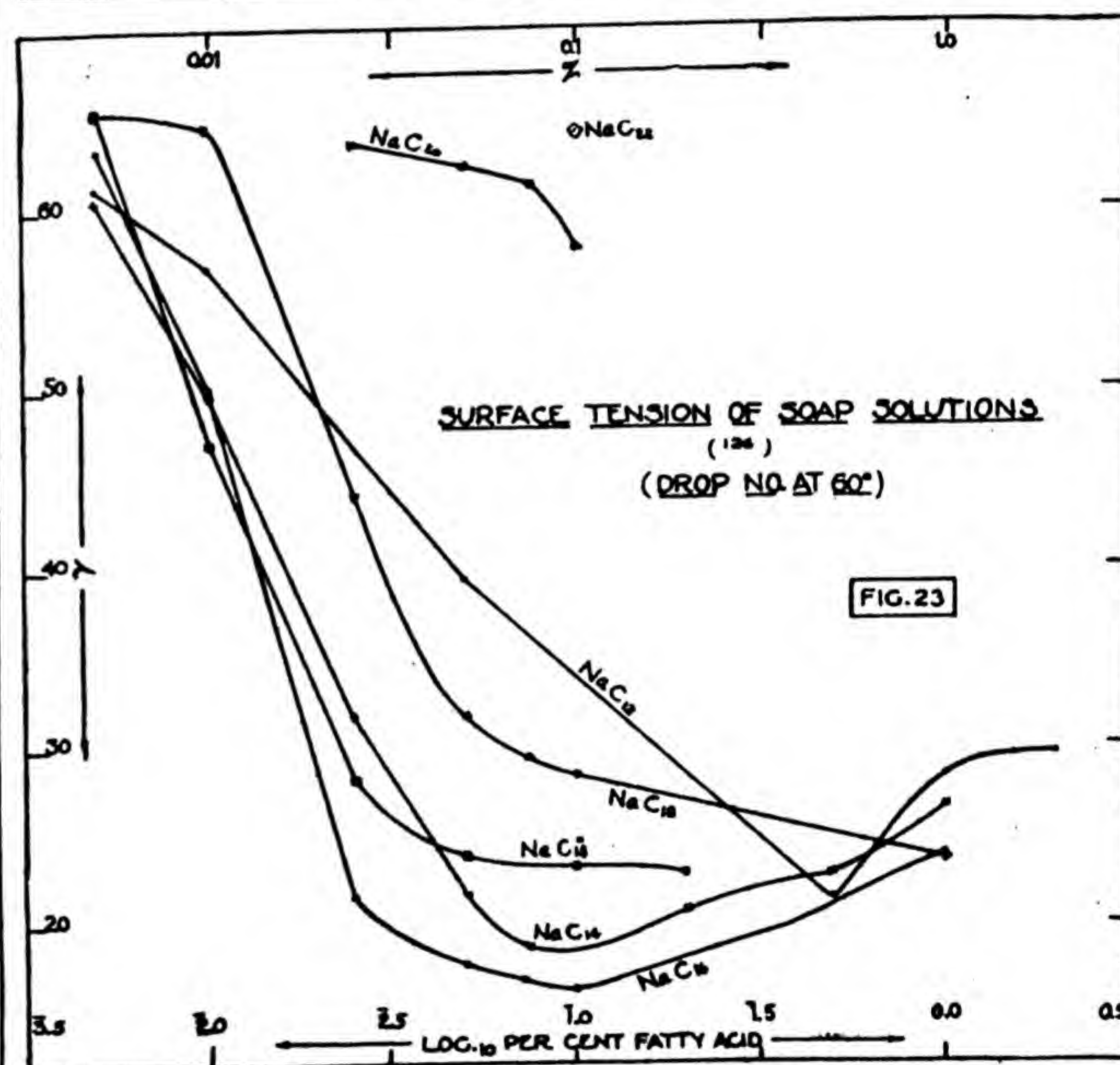


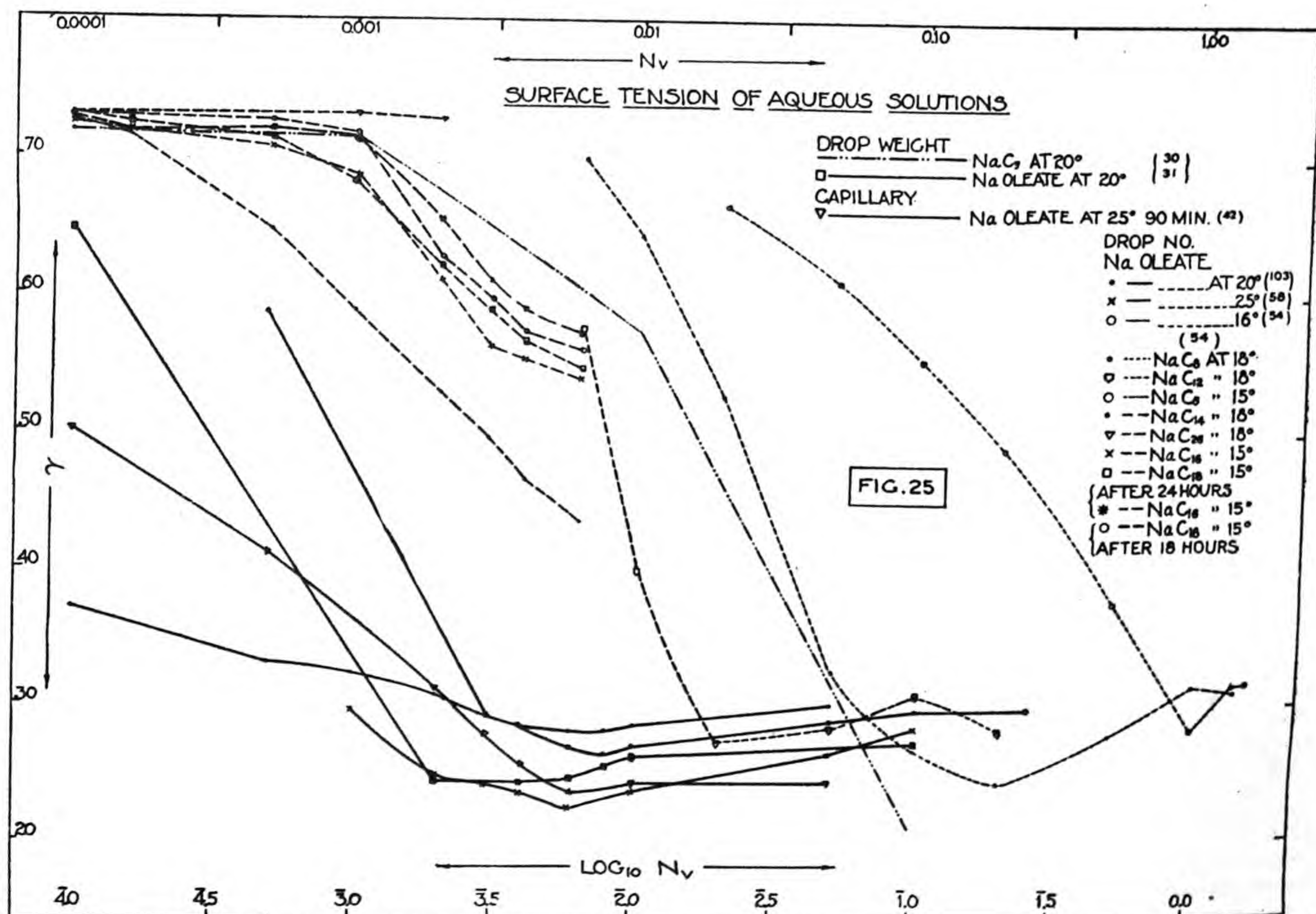
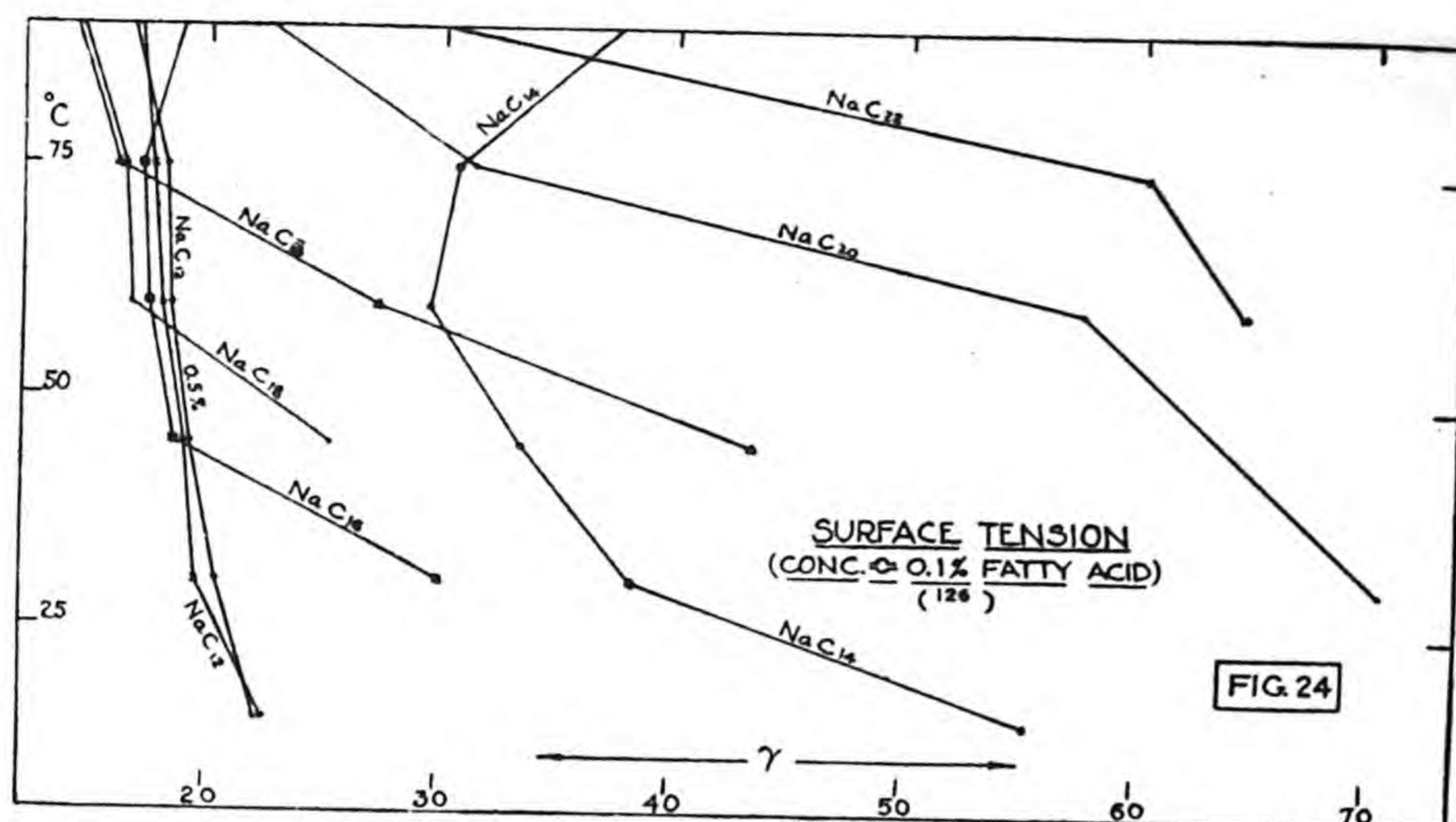
FIG. 23

#### Melting Points of the Pure Soaps

$\text{MP}_1$  is the melting point to form an anisotropic liquid,  $\text{MP}_2$  the transition to an isotropic liquid.

Soap (125)	$\text{MP}_1, ^\circ\text{C}$	$\text{MP}_2, ^\circ\text{C}$	Soap (125)	$\text{MP}_1, ^\circ\text{C}$	$\text{MP}_2, ^\circ\text{C}$
$\text{NaC}_6$	225	350	$\text{NaC}_{14}$	240	330
$\text{NaC}_7$	240	350	$\text{NaC}_{16}$	220	265
$\text{KC}_7$	225	(400)	$\text{NaC}_{18}$	225	270
$\text{NaC}_8$	225	355	$\text{NaC}_{18}$	215	316
$\text{NaC}_9$	218	242	$\text{NaC}_{18}$	220	305
$\text{NaC}_{10}$	220	318	$\text{KC}_{12}$ (72)	264	276
$\text{NaC}_{12}$	229	310			







## Melting Points.—(Continued)

Soap	MP, °C	Soap	MP, °C
(46)		AgC <sub>16</sub> .....	209 (39)
NaC <sub>12</sub> .....	255-260	AgC <sub>18</sub> .....	205 (39)
NaC <sub>14</sub> .....	250	(98)	
NaC <sub>16</sub> .....	270	PbC <sub>6</sub> .....	73.5
NaC <sub>18</sub> .....	260	PbC <sub>7</sub> .....	91
NaC <sub>18</sub> <sup>-</sup> .....	232-235	PbC <sub>8</sub> .....	84
Na elaidate.....	225-227	PbC <sub>9</sub> .....	94.5
Na erucate.....	230-235	PbC <sub>10</sub> .....	100
Na brassidate.....	245-248	PbC <sub>12</sub> .....	103.5
(39)		PbC <sub>14</sub> .....	107
PbC <sub>12</sub> .....	104.7	PbC <sub>16</sub> .....	112
PbC <sub>14</sub> .....	108.7	PbC <sub>18</sub> .....	125
PbC <sub>16</sub> .....	112.3	PbC <sub>18</sub> <sup>-</sup> .....	45-50
PbC <sub>18</sub> .....	115.7	(59)	
MgC <sub>12</sub> .....	150.4	NH <sub>4</sub> C <sub>8</sub> .....	70-85
MgC <sub>14</sub> .....	131.6	NH <sub>4</sub> C <sub>12</sub> .....	75
MgC <sub>16</sub> .....	121.5	NH <sub>4</sub> C <sub>14</sub> .....	79-90
MgC <sub>18</sub> .....	132	NH <sub>4</sub> C <sub>18</sub> <sup>-</sup> .....	57.5
LiC <sub>12</sub> .....	229.5	CuC <sub>16</sub> .....	>100
LiC <sub>14</sub> .....	223.9	CuC <sub>18</sub> <sup>-</sup> .....	100
LiC <sub>16</sub> .....	224.5	For MgC <sub>16</sub> , and MgC <sub>18</sub> , v.	
LiC <sub>18</sub> .....	221	(36); for other NH <sub>4</sub> soaps, v.	
AgC <sub>12</sub> .....	212.5	(13); for mixtures of NaC <sub>16</sub> and	
AgC <sub>14</sub> .....	211	HC <sub>16</sub> , v. (20).	

## Phase Equilibria

## Systems soap-water and soap-water-salt

**Explanatory Notes.**<sup>1</sup>—Any soap mixed with water in various proportions and under suitable conditions, can be made to assume any one of five different forms, each of which behaves as a single phase when in equilibrium with another phase. They are: (1) Lamellar crystals of soap. (2) The crystalline curd fibers of soap curd. (3) "Neat soap"—clear, transparent, plastic anisotropic liquid. (4) "Middle soap"—anisotropic. (5) Isotropic soap solutions, which includes all the more dilute solutions.

Addition of the third component, salt, introduces no new forms but the limits of concentration for the existence of the separate phases are affected.

Figures 26, 27 and 28 illustrate the limits of existence and the compositions of the various forms of soap solution with varying temperatures in the two-component system, soap-water. Figures 29-34 are the equilibrium diagrams for systems soap-water-salt at various fixed temperatures. Compositions on these triangular diagrams are in "mole fractions" based upon a fictitious molecular weight of 1000 for H<sub>2</sub>O and using the gram-formula-weights for the soap and the salt.

Similar phase-rule diagrams (such as Figures 35, 36 and 37) have been partially constructed for commercial soaps from the scattered fragmentary data of the early workers (4, 93, 115, 123, 124); see also (1), demonstrating that the phase rule is of general application to all soaps, pure and commercial, and that the same phases occur in every soap system, the limits of concentration for the existence of each phase varying with the soap.

Tables 1-4 show the relative and minimum absolute amounts of various salts required to produce phase separation at 100°, Tables 1-3 referring to formation of liquid layers and Tables 3 and 4 to beginning separation of crystalline curd fibers. These ratios are approximately independent of the nature of the soap. The effects of mixtures of electrolytes are approximately additive. A mixture of soaps behaves as expected from the constituents when forming liquid layers but not when crystallizing in either curd

<sup>1</sup> For full discussion, see (1).

or fiber form. These rules applied to the tables enable approximate prediction of the behavior of any soap or soap mixture. The following are maximum concentrations of salt for the formation of the liquid-liquid system nigre-lye with soaps made from separate oils studied by Merklen (93) the numbers being accurate to 0.1 or 0.2 of the values given: Sesame oil 6.8, olive 8.1, poppy seed 6.6, poppy seed reheated 7.7, lard 6.0, lard without salt 7.2, tallow 7.0, linseed 7.5, sulfur oil 13.3, saponification olein 8.6, saponification olein with glycerol 9.1, saponification stearin 6.2, cottonseed oil 8.9, peanut oil 6.7, castor oil 25.1, castor oil and peanut oil 17.6%.

TABLE 1 (1, 115).—MINIMUM NUMBER OF GRAMS OF VARIOUS ELECTROLYTES IN 100 CM<sup>3</sup> OF LYE AT 100° REQUIRED TO MAINTAIN TWO LIQUID LAYERS (NIGRE AND LYE) FROM POTASSIUM AND SODIUM SOAPS, IN DILUTIONS BETWEEN  $N/8$  AND  $N/4$  (1).

Electrolyte	KOH*	KCl	K <sub>2</sub> CO <sub>3</sub>	NaOH	NaCl†	Na <sub>2</sub> CO <sub>3</sub>
Stearate C <sub>18</sub> .....	7	8	13	3		6
Oleate C <sub>18</sub> <sup>-</sup> .....	8		15	4	5	7
Palmitate C <sub>16</sub> .....	10	12	18	4	5	8
Linolate C <sub>18</sub> <sup>-</sup> .....	10	13	19			
Myristate C <sub>14</sub> .....	15	20	26	8	8	16
Laurate C <sub>12</sub> .....	21		34	12	13	
Ratios.....	1.50	2.00	2.78	0.87	1.00	1.84

N.B.—An equal mixture of sodium oleate and sodium myristate is half way between pure sodium oleate and pure sodium myristate.

\* KC<sub>2</sub>H<sub>3</sub>O<sub>2</sub> by 3 g of KOH.

† NaC<sub>23</sub> by 2.3 g NaCl per 100 cm<sup>3</sup> = 0.4N<sub>w</sub> (52).

TABLE 2 (83).—CONCENTRATIONS,  $N_w$ , OF VARIOUS SODIUM SALTS REQUIRED TO SALT OUT 0.25N<sub>w</sub> SOLUTIONS OF SODIUM PALMITATE AT 90°

Anion	$N_w$	Anion	$N_w$	Anion	$N_w$
OH.....	1.13	Br.....	0.90	CNS.....	0.76
NO <sub>3</sub> .....	1.05	C <sub>2</sub> H <sub>3</sub> O <sub>2</sub> .....	0.89	WO <sub>4</sub> .....	0.65
Cl.....	0.95	CO <sub>3</sub> .....	0.89	Tartrate.....	0.65
I.....	0.91	SO <sub>4</sub> .....	0.83		

TABLE 3 (1, 115).—RELATIVE NUMBER OF MOLES OF HYDROXIDE, CHLORIDE, AND CARBONATE OF SODIUM AND POTASSIUM REQUIRED FOR SALTING OUT LIQUID LAYERS OR CURD AT 100°.

	OH	Cl	CO <sub>3</sub>
K.....	1.02	1.00	0.70
Na.....	1.27	1.00	1.01

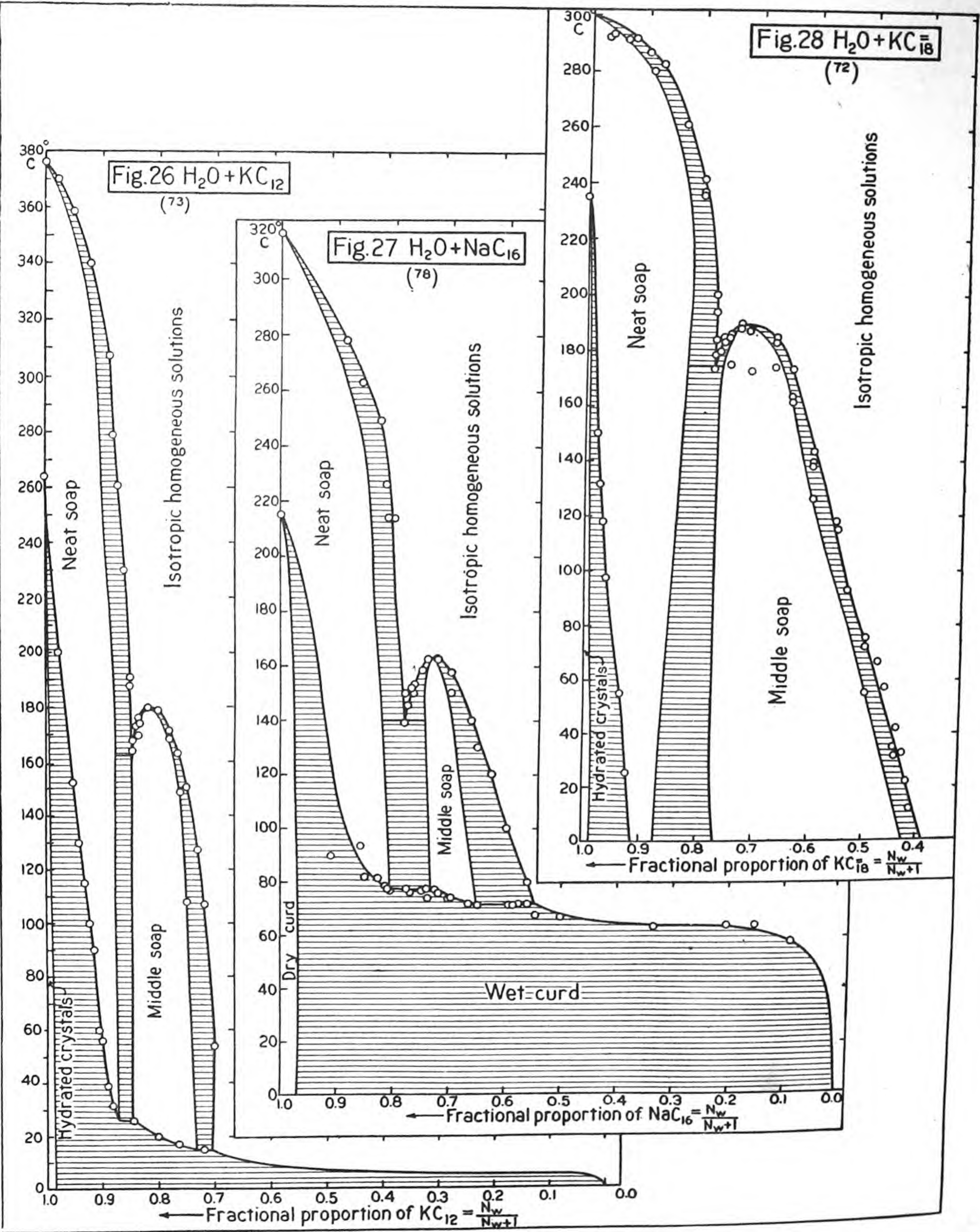
TABLE 4 (1, 115).—MINIMUM NUMBER OF GRAMS OF VARIOUS ELECTROLYTES IN 100 CM<sup>3</sup> LYE AT 100° FOR CURD FIBERS TO APPEAR IN NEAT SOAP LAYER.

Electrolyte	KOH	KCl	K <sub>2</sub> CO <sub>3</sub>	NaOH	NaCl	Na <sub>2</sub> CO <sub>3</sub>
Stearate C <sub>18</sub> .....	(17)	13	20	4		7
Oleate C <sub>18</sub> <sup>-</sup> .....	10		19.5	4	5	9
Palmitate C <sub>16</sub> .....	11		22	5	6	12
Linolate C <sub>18</sub> <sup>-</sup> .....	13	19	24			
Myristate C <sub>14</sub> .....	18	>23	>38	9	10	17.8
Laurate C <sub>12</sub> .....	25		>37	13	14	
Ratios.....	1.50	2.00	2.78	0.87	1.00	1.84

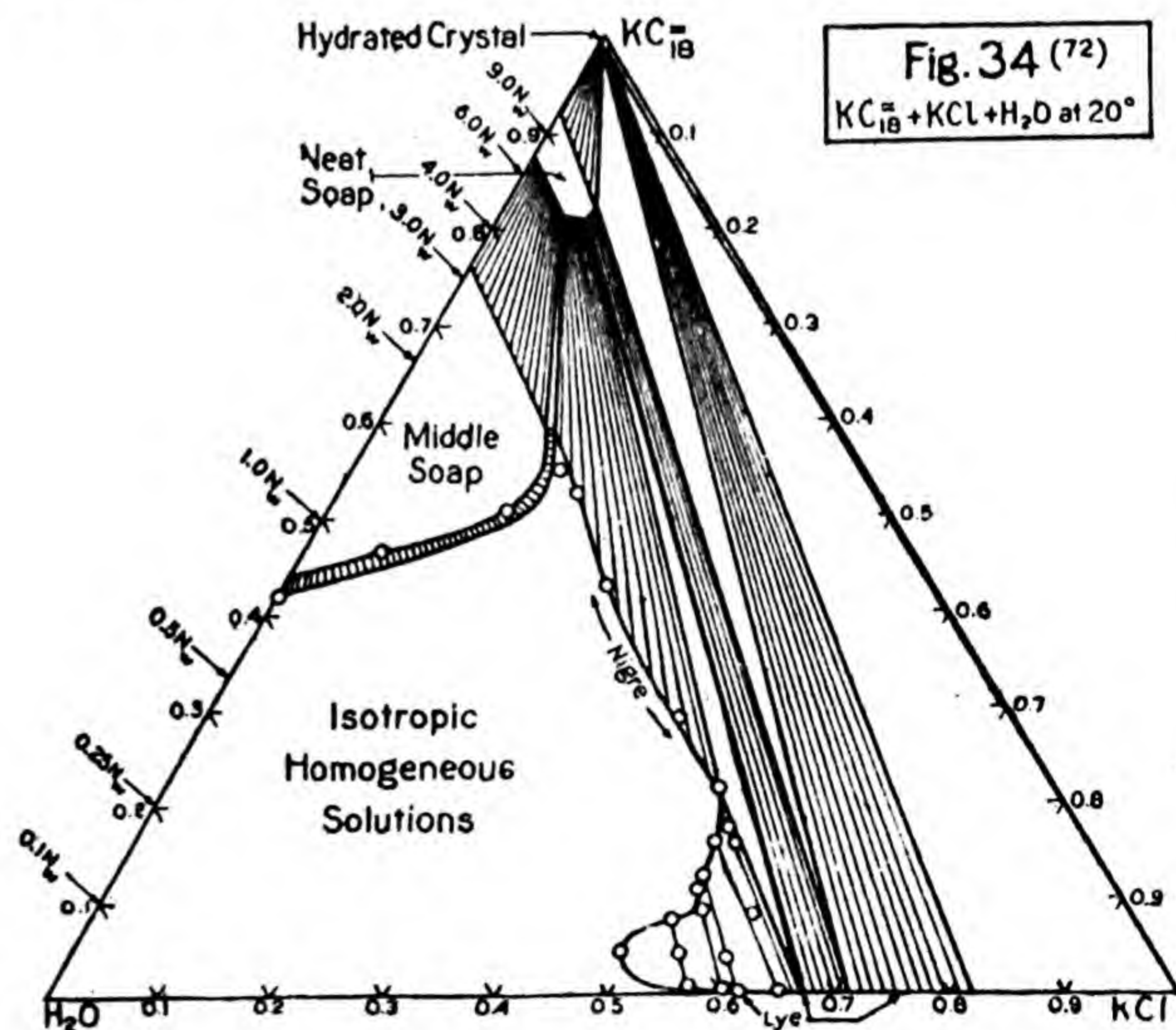
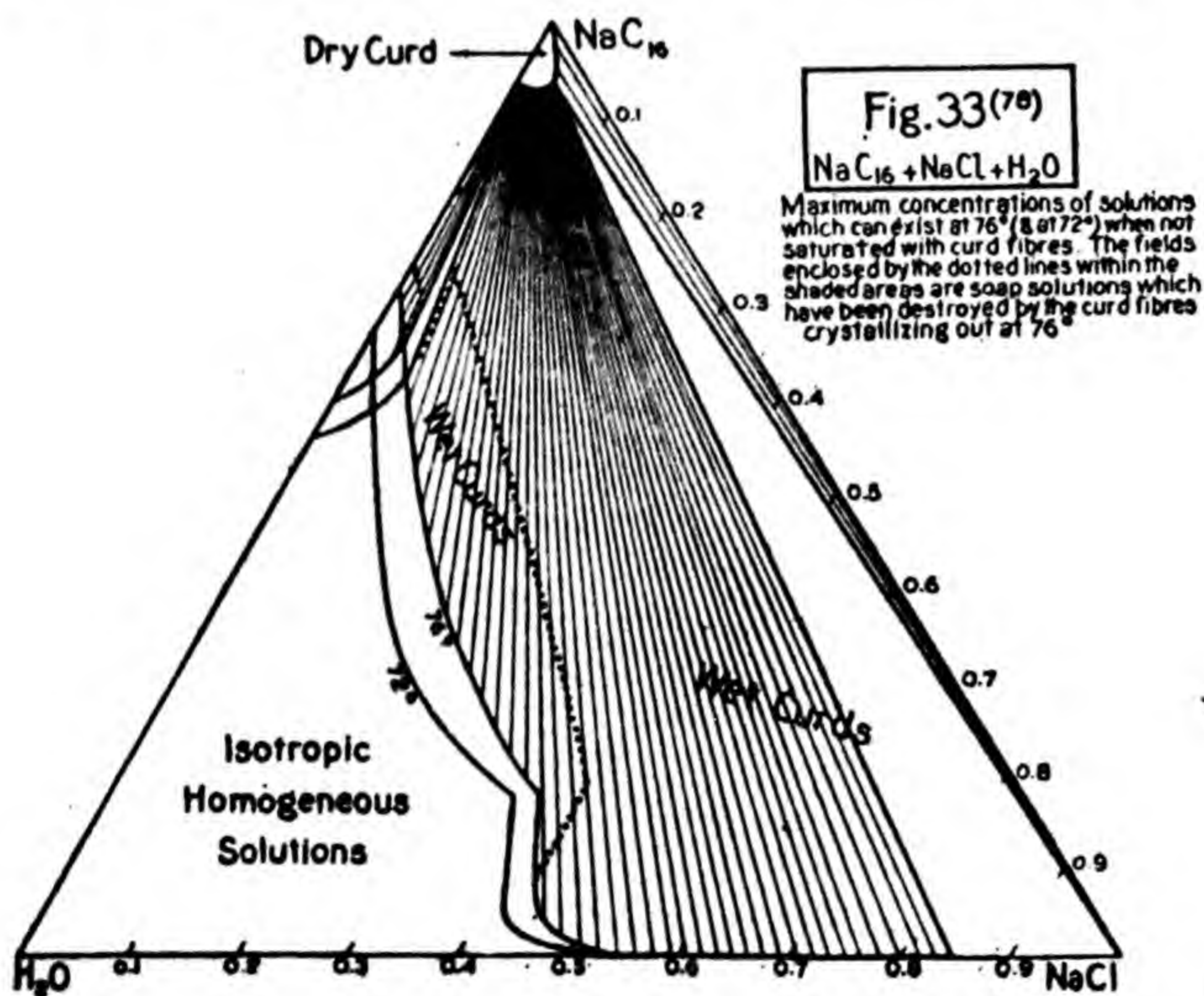
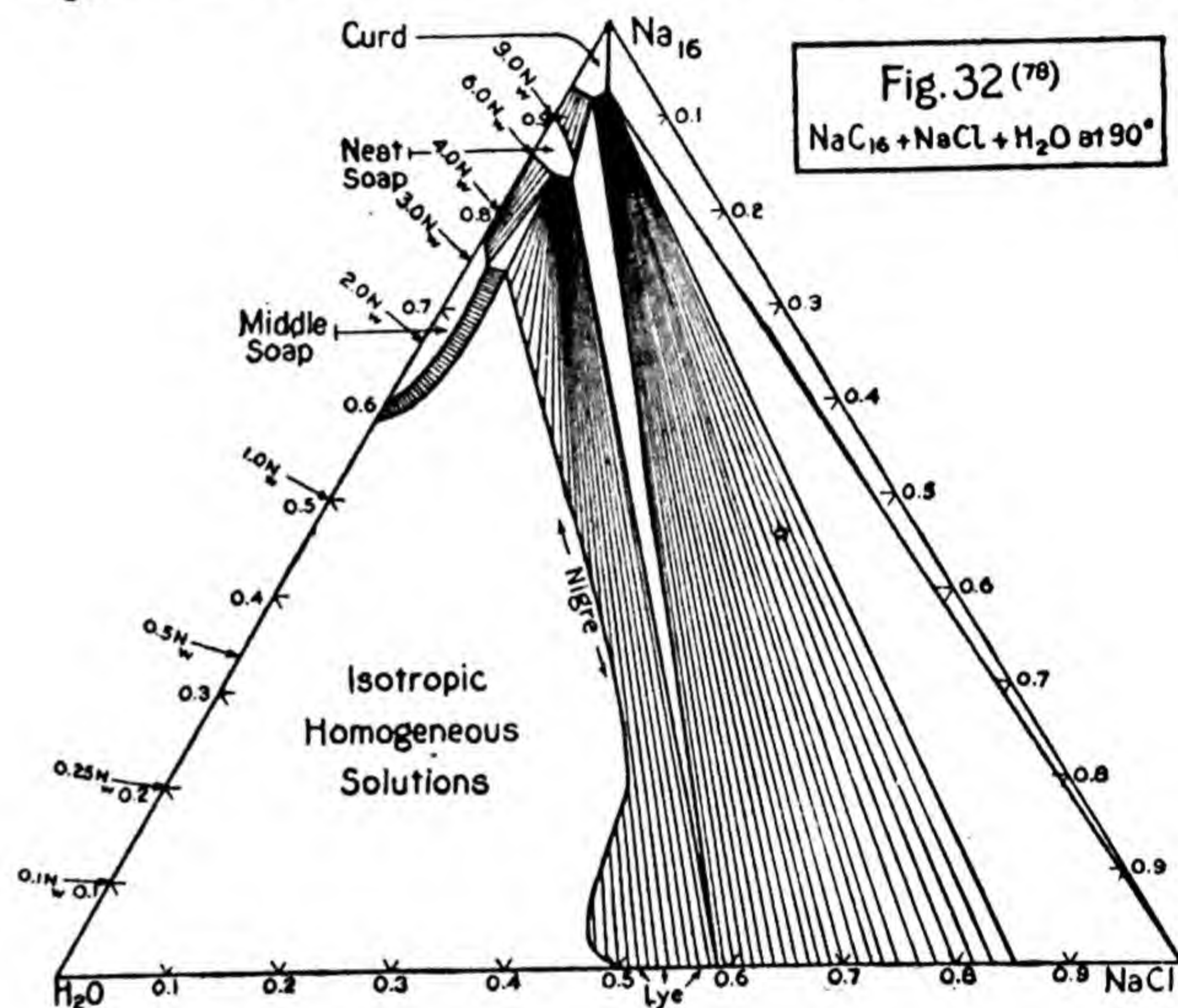
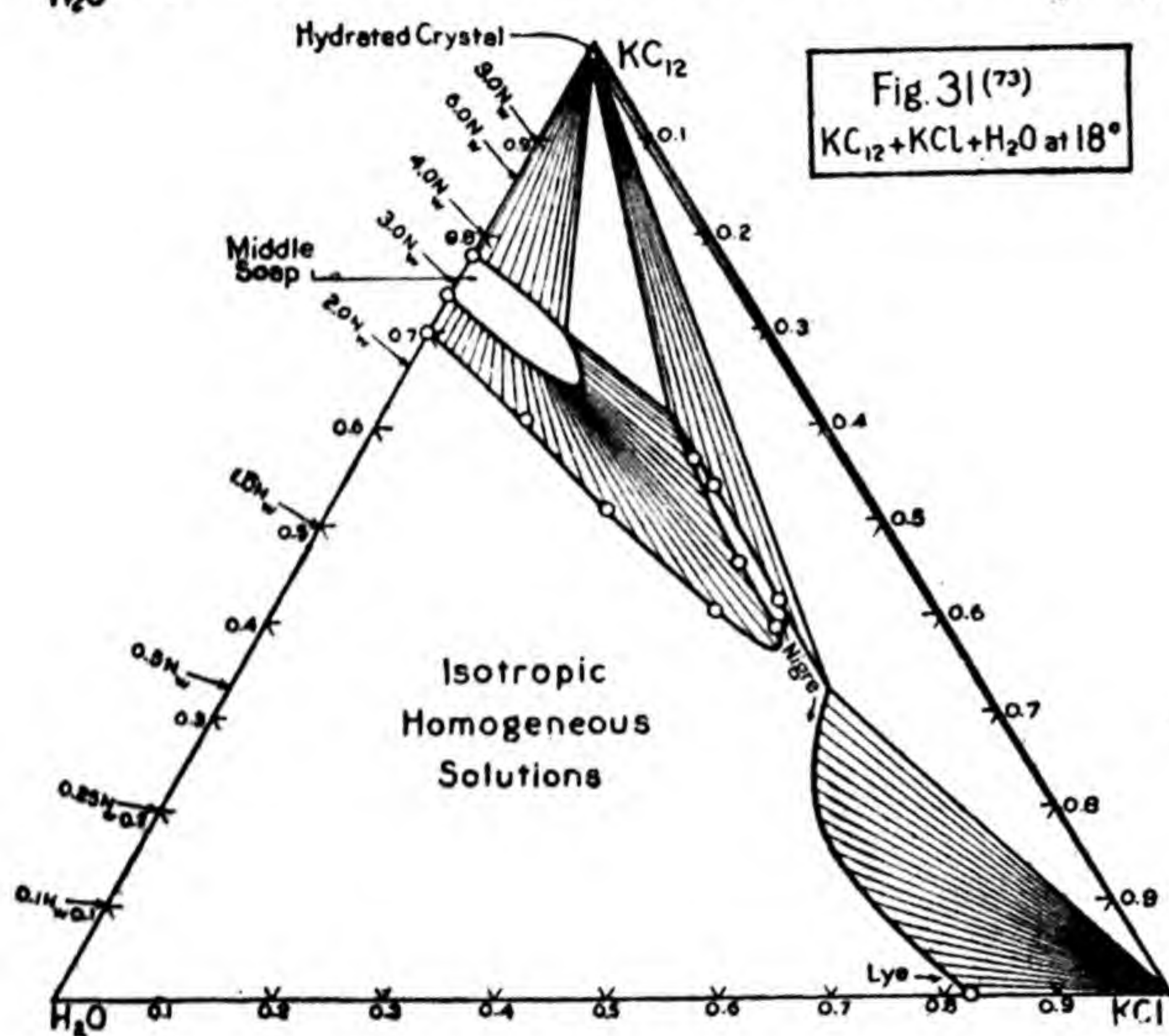
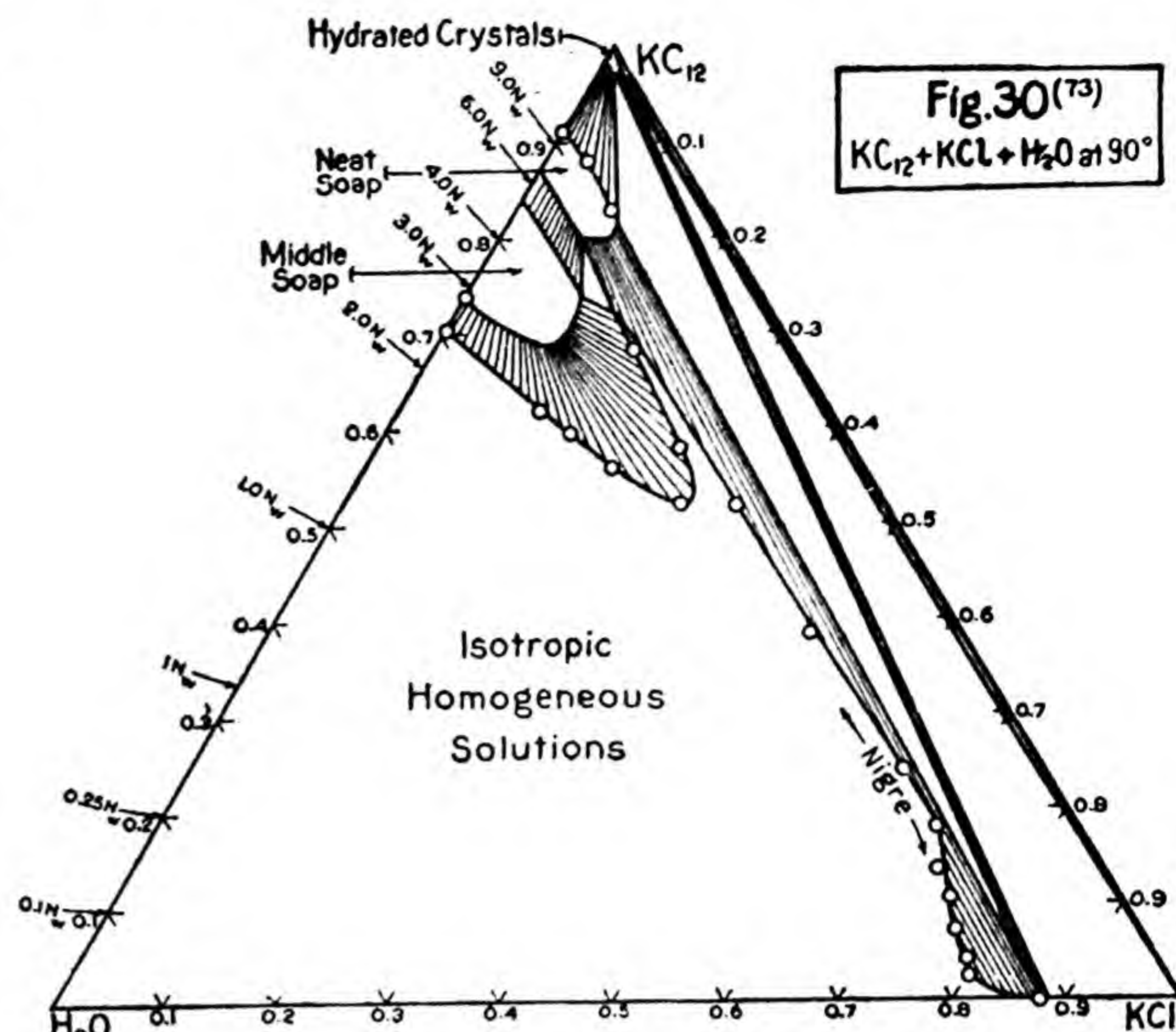
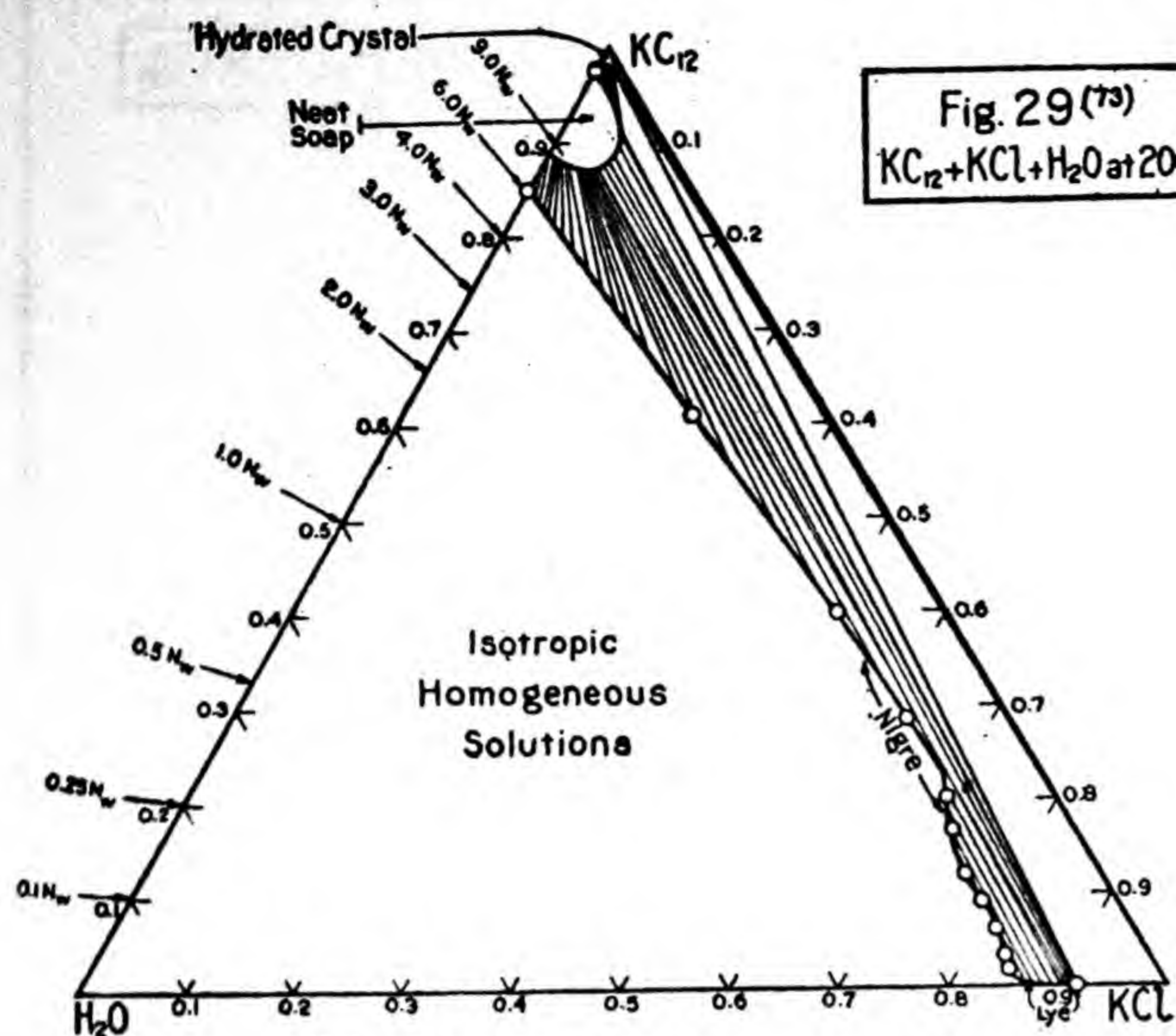
N.B.—Notice that the values for sodium salts are about half those for the corresponding potassium salts.

\* Langdon (78) for NaC<sub>16</sub> found 7% NaCl, Stiepel (122) for NaC<sub>12</sub>, NaC<sub>14</sub>, NaC<sub>16</sub> and NaC<sub>18</sub> found 18, 9, 7, and 5% NaCl respectively, as compared with Richert's 14, 10.6 and 5%. Kronacher (25) for NaC<sub>10</sub>, NaC<sub>12</sub>, NaC<sub>14</sub>, NaC<sub>16</sub> and NaC<sub>18</sub> found approximately 23, 13, 10, 7 and 5% NaCl.

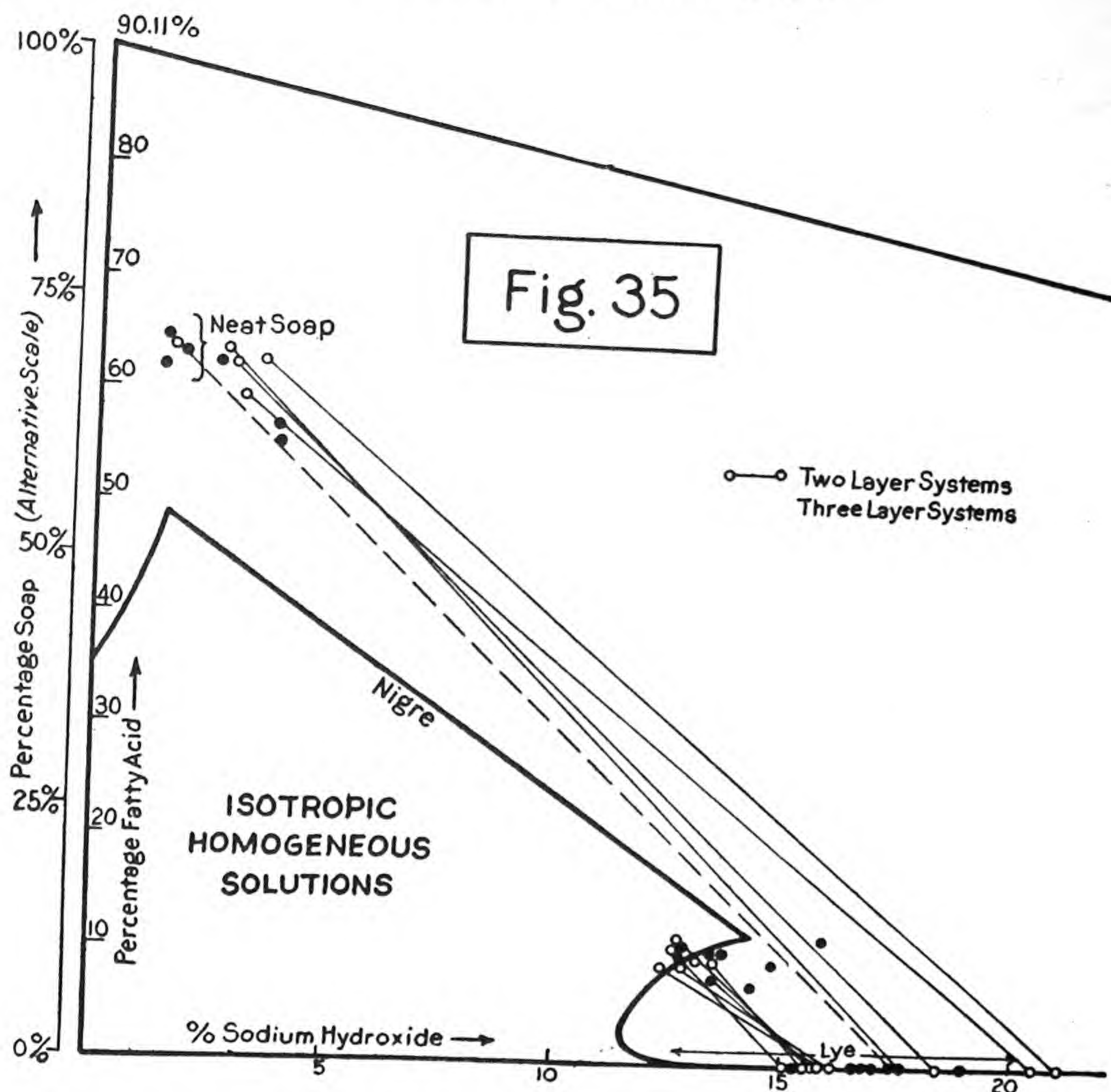












### Solubility

Any soap, pure or commercial, mixed with water or with water and an electrolyte can be made to exist as either lamellar soap crystals or curd fiber crystals; both are usually hydrated, and more than one hydrate may occur. On raising the temperature the crystals or curd dissolve to form ordinary isotropic solution, middle soap, or neat soap depending upon the concentration. The data usually refer to the form of hydrated crystals most stable under the experimental conditions.

HYDRATED CURD FIBERS; TEMPERATURE OF COMPLETE SOLUTION TO FORM ISOTROPIC SOLUTION OF CONCENTRATION,  $N_w$

$N_w$	°C	$N_w$	°C	$N_w$	°C	$N_w$	°C
NaC <sub>12</sub> (69)		NaC <sub>16</sub> (78)		KC <sub>18</sub> (10)		KC <sub>12</sub> (73)	
2.0	45	10.0	(90)	15	55	8.004	39.0
1.0	40	1.009	67	12	26	8.878	56.0
0.2	34	0.504	63	KC <sub>12</sub> (73)		9.694	60.0
0.1	31	0.01	51	2.508	15	10.98	90.0
NaC <sub>18</sub> (53)		KC <sub>18</sub> (72)		3.222	17.5	11.52	100
0.6	25	50	150	4.004	20.0	12.96	100
0.4	23	40	132	5.373	25.5	16.14	130
0.2	21	30	118	5.653	26.0	19.36	152
0.1	18	25	98	7.226	32.0	43.32	200

FIGS. 35 and 36 (1).—A reinterpretation (by J. W. McBain) of M. Thörl's laboratory experiments with sodium hydroxide on the salting out of soap prepared from coconut oil at 100°C showing how they accord with phase-rule diagrams for the pure soaps.\*

\* The boundary line of the isotropic solutions is sketched in an identical position in diagrams 35, 36 and 37 and takes account of results of Perkowski quoted by Richert. Results of Thörl, Bätz, Richert and Perkowski are not true per cent but grams per 100 cm<sup>3</sup> of solution measured at 100°C. The data of Penny and Elford are grams per 100 grams of total system.

SOLUBILITY OF HYDRATED CURD FIBERS IN TERMS OF  $N_w$  OF MOTHER LIQUOR IN CURD AFTER SOLIDIFICATION ( $=N_w$  IN TABLE)

Soap	Orig. $N_w$	$N_w$	$t$ , °C	Lit.
NaC <sub>10</sub> .....	2	1	15	(12)
NaC <sub>16</sub> .....	0.1914	0.01778	30	(53)
	0.25	0.00819	25	
NaC <sub>18</sub> *.....	0.25	0.03	17-25	(6)
	1.0	0.1	17-25	
NaC <sub>16</sub> .....	0.005-0.0004	0.0003	17	(112)
NaC <sub>18</sub> .....	0.6	0.39	18	(53)
		0.26	10	
		0.114	0	
	0.1905	0.0998	18	

\* NaC<sub>18</sub> dissolved in 0.6  $N_w$  aqueous glycerol.



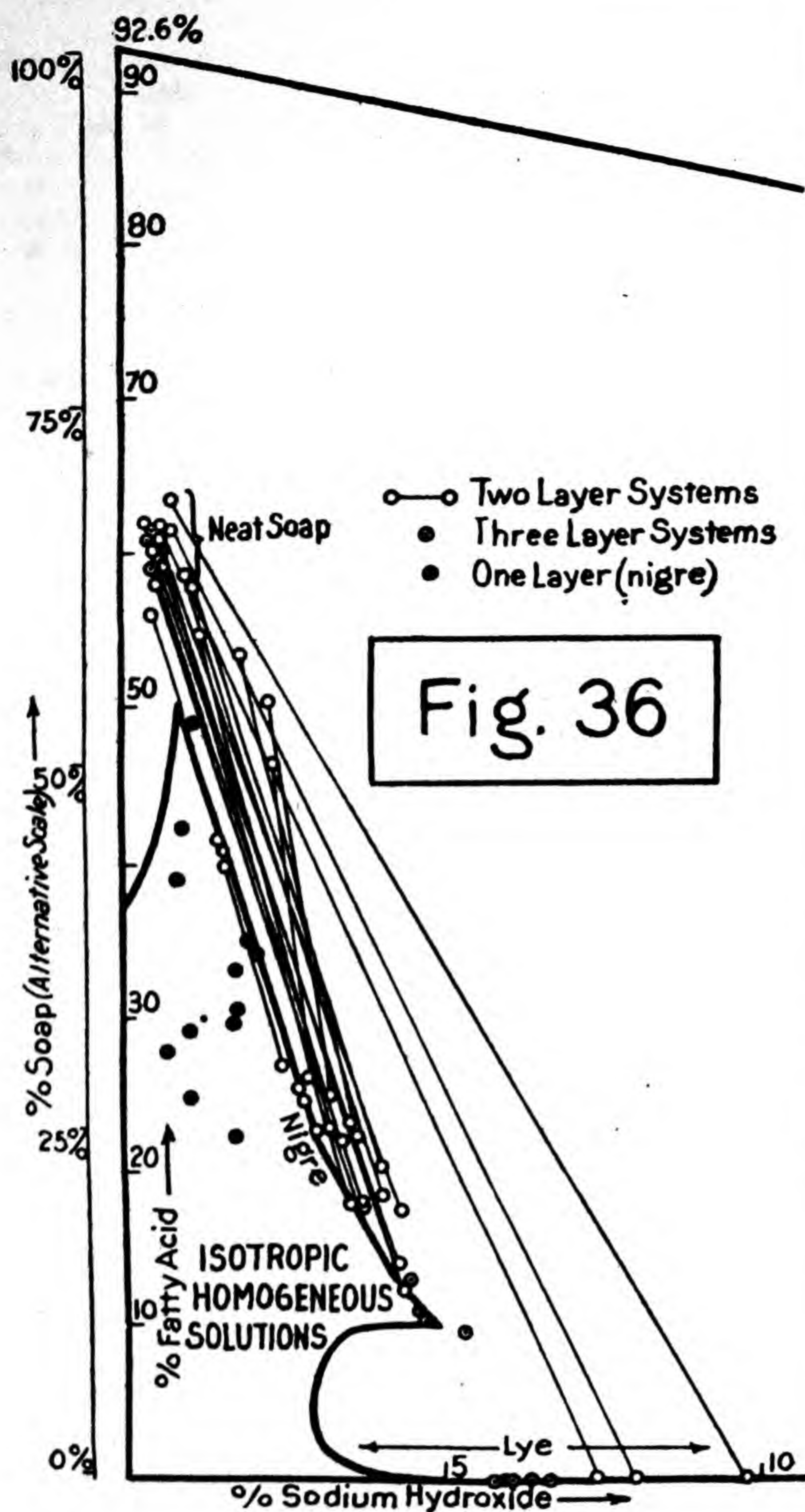


Fig. 36

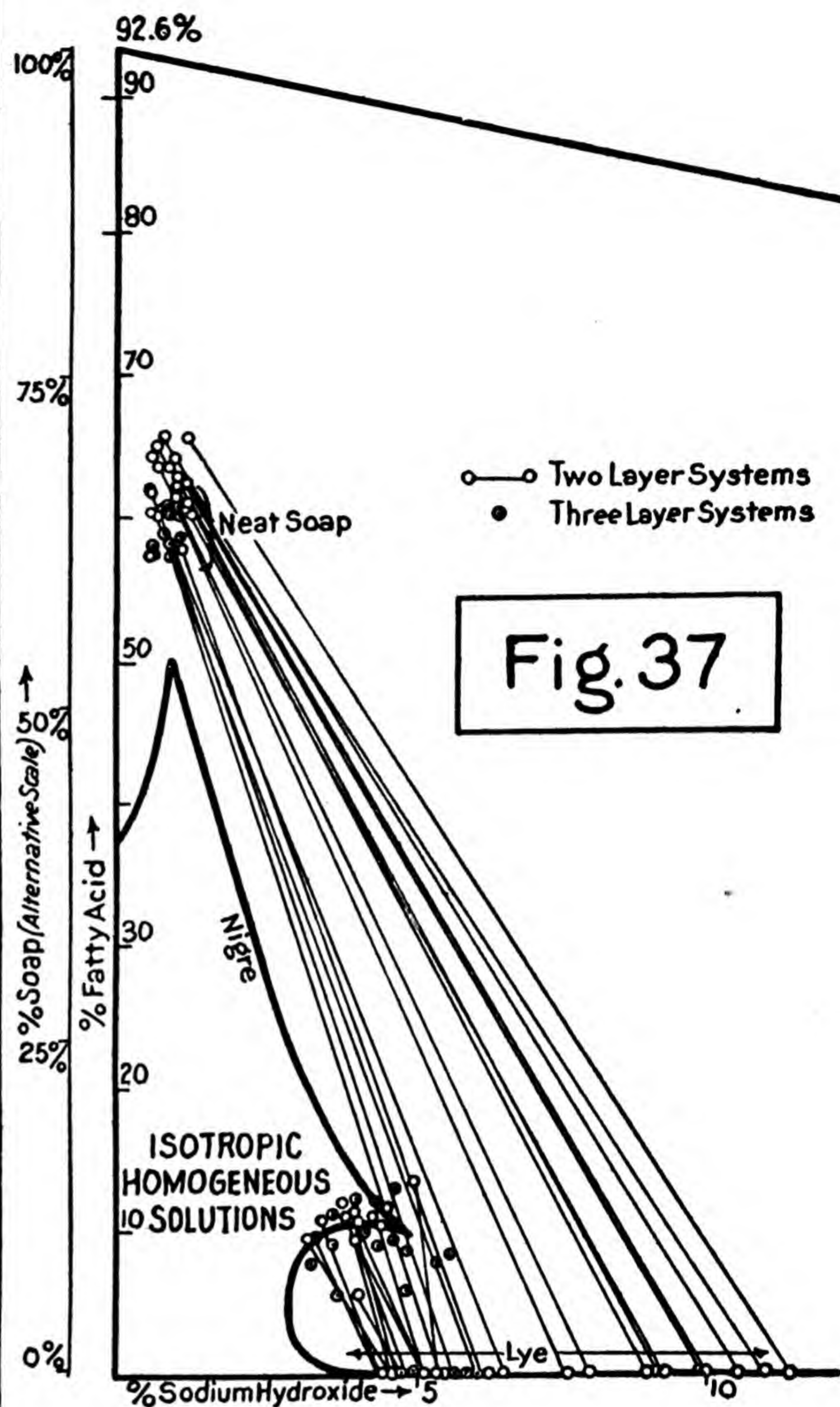


Fig. 37

SOLUBILITY OF CURD FIBERS AS DETERMINED FROM FATTY RADICAL FROM CURD

Soap	$N_w$		$t, ^\circ\text{C}$	Lit.
	Curd	Ultrafiltrate		
$\text{NaC}_{18}$ .....	0.04-0.009	0.0003	18	(55)
	0.003-0.006	0.00023	18	
$\text{KC}_{18}$ .....	0.034	0.0002	22	(50)
$\text{NaC}_{18}$ .....	0.065	0.0004-0.0006	14-18	(50)
	0.03	0.0001*	18-22	
	0.03	0.0004-0.0005	14-18	
	0.0013	0.0001	14-18	

\* Assumed by Kratz to be correct solubility.

TEMPERATURE OF SPONTANEOUS SEPARATION OF Na SOAP (CURD FIBERS) FROM AQUEOUS SOLUTION ON COOLING,  $^\circ\text{C}$  (47)

Soap, g per 100 g $\text{H}_2\text{O}$	$\text{C}_{18}$	$\text{C}_{16}$	$\text{C}_{14}$	$\text{C}_{12}$	$\text{C}_{10}$	Elai-date	$\text{C}_{23}$	Brass-ide
1	60°	45°	32°	11°	0°	35°	27°	42°
20	69°	62°	53°	(36°)	ca. 13°	45°	35°	56°
(12)	3	2	1.5	1	0.75 $N_w$			
$\text{NaC}_8$ .....	13-14°	10-11°	-1°	<0°				
$\text{NaC}_{10}$ .....		16°	3-4°	2.3°	>0°			

Also (108); 6%  $\text{NaC}_{12}$  at 26°, 1%  $\text{NaC}_{16}$  at 43°, 6%  $\text{NaC}_{18}$  at 52°, 1%  $\text{NaC}_{18}$  + 6%  $\text{NaC}_{12}$  at 8°, 1%  $\text{NaC}_{18}$  + 1%  $\text{NaC}_{12}$  at 29°; (3)  $\text{NaC}_{18}$ , 0.1  $N_w$  at 58°, 0.5  $N_w$  at 65°;  $\text{KC}_{18}$ , 0.5  $N_w$  at 38°C; (12) 62.5 g anhyd.  $\text{NaC}_{12}$  in 100 g  $\text{H}_2\text{O}$  at 12-18°.



## Solubility.—(Continued)

## TEMPERATURE OF COMPLETE SOLUTION OF HYDRATED CRYSTALLINE CURD FIBERS IN AQUEOUS NaCl SOLUTIONS

NaC <sub>12</sub> (69)			KC <sub>12</sub> (73)		NaC <sub>18</sub> (78)		
N <sub>w</sub> soap	N <sub>w</sub> NaCl	°C	N <sub>w</sub> soap	°C	N <sub>w</sub> soap	N <sub>w</sub> NaCl	°C
2.0	0.534	57	N <sub>w</sub> KCl = 0.5		3.02	0.293	(77)
	0.62	56	6.01	(21.0)	1.01	.680	76
	1.02	60	6.99	29.0	0.504	.794	74
	1.02	63.5	7.46	35	.504	.55	72
	1.92	68	8.76	50	.504	.642	76
1.0	0.49	48	9.77	65	.503	.738	75.5
	1.59	60	11.2	90	.399	.906	76
	1.66	65	12.6	100	.351	.835	75
	1.71	62	20.0	115	.206	.836	74
	1.86	63	N <sub>w</sub> KCl = 1.0		.135	.819	72.5
	2.10	66	6.01	24.5	.0610	.807	72.5
0.20	1.21	55	7.91	50.5	.058	.908	(75)
	1.56	60	8.93	79.0	NaC <sub>22</sub> (52)		
	2.05	61	9.8	90.0	0.05	0.42	100
0.10	1.97	60	15.0	98.0	0.05	0.59	100
	2.08	61	N <sub>w</sub> KCl = 2.0				
	2.19	62	5.02	33.5			
			5.97	35.2			
			7.70	41.5			

## GRAMS OF SOAP IN 100 GRAMS OF WATER AT VARIOUS TEMPERATURES

	15°	25°	50°	100°C	Lit.
LiC <sub>12</sub> .....		0.180	0.280		(39)
LiC <sub>14</sub> .....		0.036	0.060		(39)
LiC <sub>16</sub> .....		0.015			(39)
LiC <sub>18</sub> .....		0.010			(39)
SrC <sub>6</sub> * + 3H <sub>2</sub> O...		8.89 (at 24°)			(45)
MgC <sub>12</sub> .....	0.009	0.009	0.026		(39)
MgC <sub>14</sub> .....	0.006	0.006	0.014		(39)
MgC <sub>16</sub> .....	0.005	0.005	0.009		(39)
MgC <sub>18</sub> .....	0.003	0.004	0.008		(39)
MgC <sub>18</sub> <sup>-</sup> .....	0.022	0.024	0.03		(92)
Mg erucate.....		0.006			(123.5)
BaC <sub>6</sub> .....	8	7	8		(29, 60, 116)
BaC <sub>7</sub> .....	1.6	1.6	1.6		(60)
BaC <sub>12</sub> .....	0.008	0.009	0.011		(39)
BaC <sub>14</sub> .....	0.007	0.008	0.010		(39)
BaC <sub>16</sub> .....	0.004	0.005	0.007		(39)
BaC <sub>18</sub> .....	0.004	0.005	0.006		(39)
CaC <sub>6</sub> .....	2.4	2.3	2.3	2.57	(29, 60, 61, 116)
CaC <sub>7</sub> †.....	0.84	0.81	0.80	1.24	(60, 116)
CaC <sub>8</sub> .....	0.31	0.29	0.26	0.50	(116)
CaC <sub>18</sub> <sup>-</sup> .....	0.04	0.04	0.03		(92)
ZnC <sub>6</sub> + H <sub>2</sub> O....		1.03 (at 24.5°)			(45)
CdC <sub>6</sub> + 2H <sub>2</sub> O....		0.96 (at 23.5°)			(45)
PbC <sub>12</sub> .....			0.007		(39)
PbC <sub>14</sub> .....			0.006		(39)
PbC <sub>16</sub> .....			0.007		(39)
PbC <sub>18</sub> .....			0.006		(39)
AgC <sub>6</sub> .....	0.09	0.12	0.20		(60, 116)
AgC <sub>7</sub> .....	0.09	0.11	0.17		(60, 116)
AgC <sub>14</sub> .....			0.007		(39)
AgC <sub>16</sub> .....			0.006		(39)
AgC <sub>18</sub> .....			0.004		(39)

\* Caproic acid from fermentation butyric acid.

† See also Landau, 1893, and Altschul, 1896 (116).

## ADDITIONAL DATA

Fahrion (21) 1 l water at 15° dissolved 90 mg of CaC<sub>18</sub><sup>-</sup> and 224 mg MgC<sub>18</sub><sup>-</sup>. Blumercron (12) curding of solutions of NaC<sub>6</sub>, NaC<sub>7</sub>, NaC<sub>8</sub>, NaC<sub>9</sub>, NaC<sub>10</sub>, at 20° on addition of NaCl and NaOH. Partheil and Ferié (107), LiC<sub>12</sub>, LiC<sub>14</sub>, LiC<sub>16</sub>, LiC<sub>18</sub> at 18° and 25°. Oudemans ((59) p. 159) Mg, Ca, Sr, Ba, Zn, Pb, Mn, Co, Ni, Cu, Ag salts of C<sub>12</sub> at 15° and at boiling point. Lewkowitsch ((59) p. 143, 157) CaC<sub>6</sub>, CaC<sub>8</sub>, CaC<sub>10</sub>, CaC<sub>12</sub> at 20° or 100°. Jensen (41) AgC<sub>8</sub>, AgC<sub>10</sub> at 20° in water and 1/20N AgNO<sub>3</sub> solution. Altschul ((116) p. 614) AgC<sub>7</sub>, 0–80°. Lieben and Janecek (61) CaC<sub>6</sub>, BaC<sub>6</sub> at 10–12°. Zsigmondy and Bachman (130) NaC<sub>16</sub> in water. McBain, Cornish and Bowden (70) NaC<sub>18</sub> in water. Kottal (45) CaC<sub>6</sub>, BaC<sub>6</sub>.

## Freezing-Point Lowering

Values of  $k_F = \Delta t_F / N_w$ , where  $\Delta t_F$  is the freezing-point lowering in °C at the concentration  $N_w$  moles per kg H<sub>2</sub>O (52).

Soap	N <sub>w</sub>	Δt <sub>F</sub>	Soap	N <sub>w</sub>	Δt <sub>F</sub>
KC <sub>12</sub> .....	0.05	0.177	KC <sub>8</sub> .....	3.0	4.71
	.1	.212	NaC <sub>18</sub> <sup>-</sup> .....	0.4	0.146
KC <sub>18</sub> <sup>-</sup> .....	.6	.348		.2	.095
	.4	.215	NaC <sub>22</sub> .....	.05	.036
NaC <sub>8</sub> .....	1.0	2.445			

See further, Fig. 38.

## Boiling-Point Elevation

Values of  $k_B = \Delta t_B / N_w$ , where  $\Delta t_B = t_s - t_w$ ,  $t_s$  being the temperature at which the partial vapor pressure of water from the solution is equal to the vapor pressure of pure water at  $t_w$ , °C. The data for the higher temperatures ( $t_w = 90 - 100^\circ\text{C}$ ) are shown graphically in Fig. 39. Some values at lower temperatures are given in the following table:

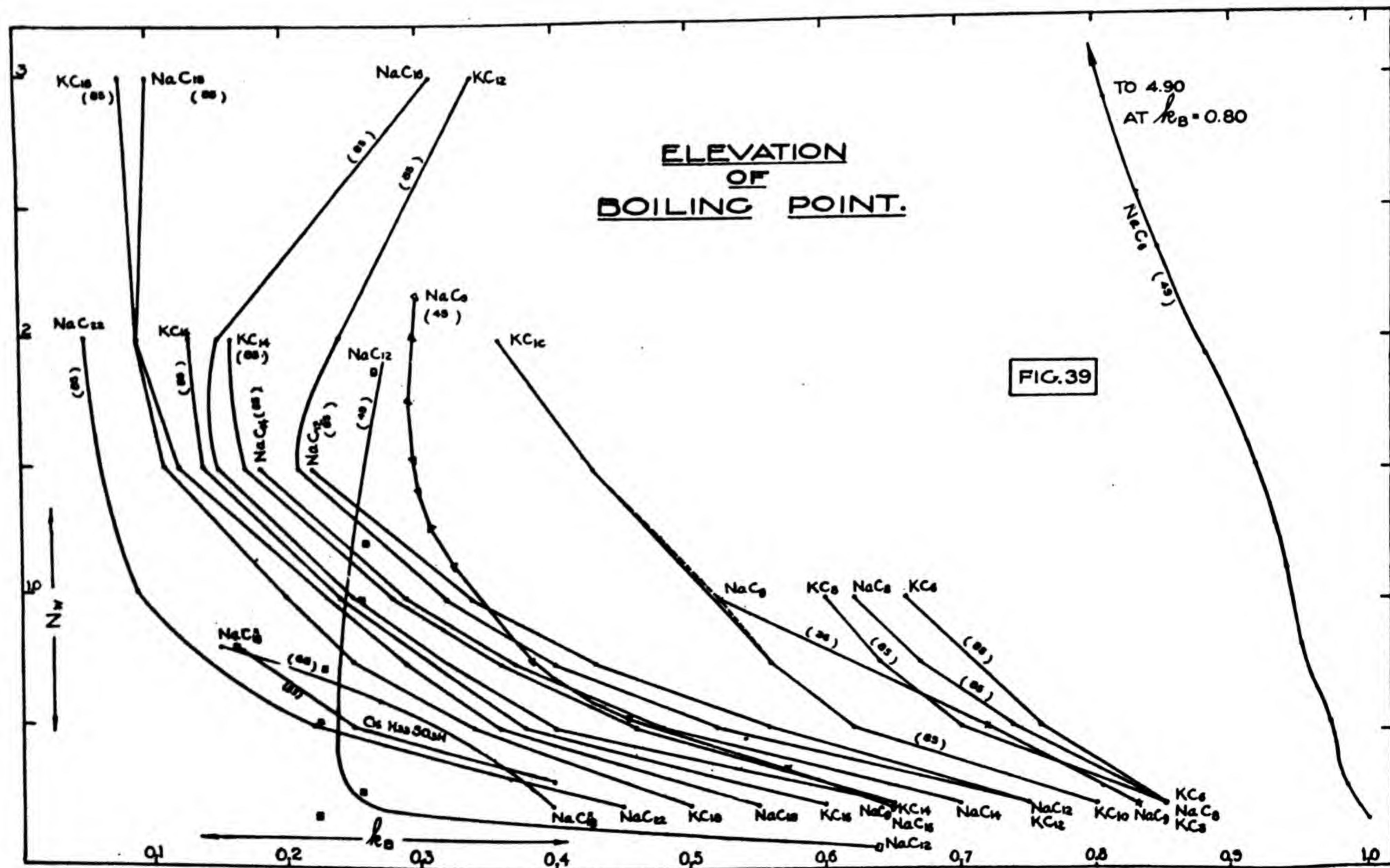
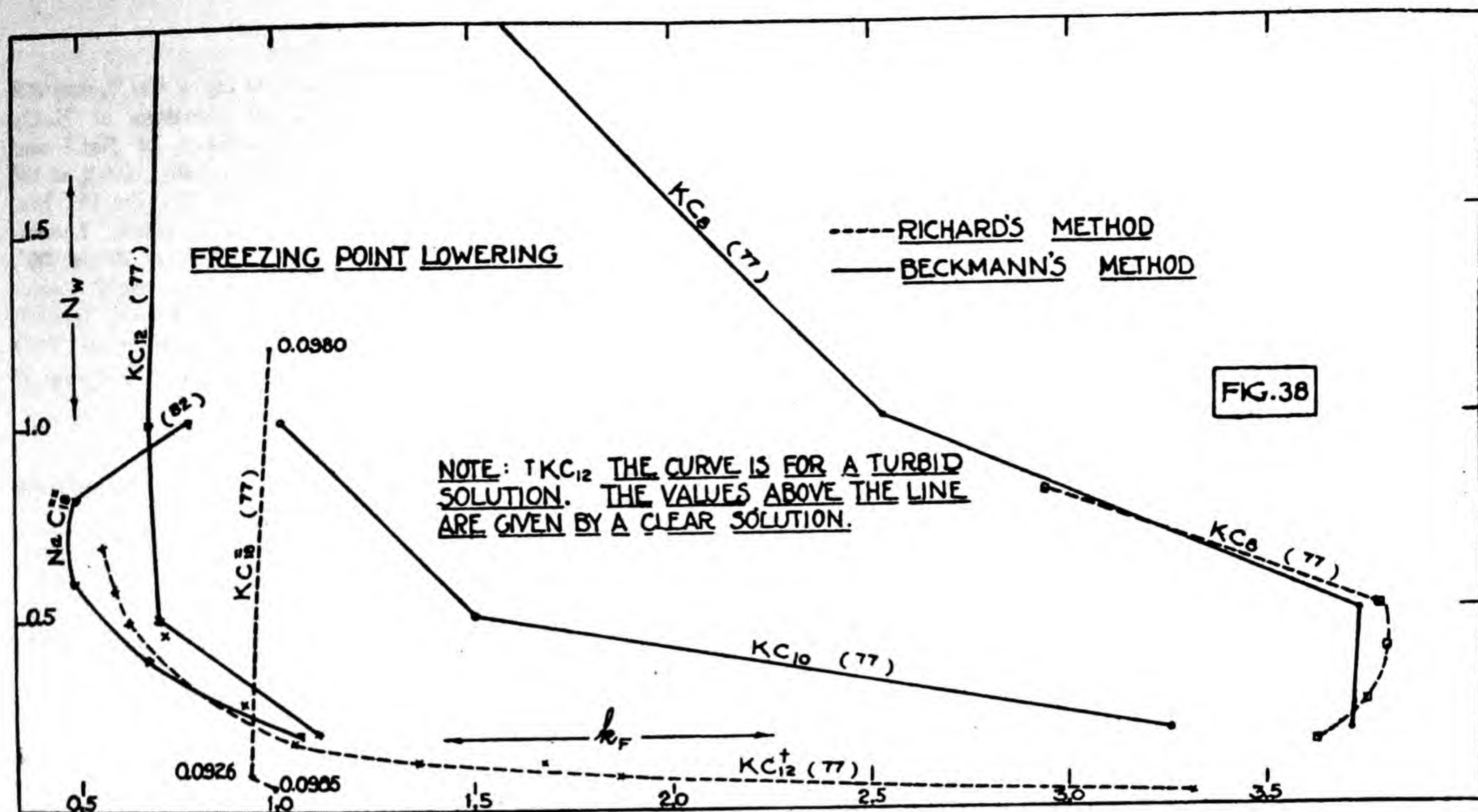
Soap*	t <sub>w</sub> , °C	N <sub>w</sub>	k <sub>B</sub>	Lit.
KC <sub>8</sub> .....	20	3.0	0.23	(77)
NaC <sub>12</sub> .....	43	1.5	.20	(86)
NaC <sub>12</sub> .....	40	1.5	.20	(86)
KC <sub>12</sub> .....	20	0.2	.20	(77)
NH <sub>4</sub> C <sub>12</sub> .....	20	1.0	.17	(77)
NH <sub>4</sub> C <sub>12</sub> .....	20	0.5	.16	(77)
NaC <sub>16</sub> .....	67	1.0	.26	(86)
NaC <sub>16</sub> .....	70	1.0	.26	(86)
KC <sub>16</sub> .....	33	0.5	.34	(86)
NH <sub>4</sub> C <sub>16</sub> .....	20	1.0	.06	(77)
NH <sub>4</sub> C <sub>16</sub> .....	70	1.0	.23	(85)
NaC <sub>18</sub> .....	18	0.6	.10	(53)
NaC <sub>18</sub> <sup>-</sup> .....	18	0.4	.10	(53)
KC <sub>18</sub> <sup>-</sup> .....	20	0.6	.12	(77)
K elaidate.....	20	0.75	.24	(68)
K elaidate.....	20	0.5	.26	(68)
K elaidate.....	20	0.2	0.6–0.8	(68)
NaC <sub>18</sub> OH.....	20	1.0	0.21	(68)
NaC <sub>18</sub> OH.....	20	0.75	.25	(68)
NaC <sub>18</sub> OH.....	20	0.5	.34	(68)
NaC <sub>18</sub> OH.....	20	0.2	.35	(68)
NaC <sub>18</sub> <sup>-</sup> .....	20	0.5	.20	(68)
NaC <sub>18</sub> <sup>-</sup> .....	20	0.2	.075	(68)

\* For solutions of soap with various added constituents, *v.* (46, 77, 85, 89, 109).

## Refractive Index (62)

The specific refraction,  $R = (n - 1)/d$  or  $R' = (n^2 - 1)/d \times (n^2 + 2)$  for soap in soap solutions at 70° is for any one soap independent of concentration (and also of solvent), the molecular refraction for the soap in solution being equal to that calculated for the pure anhydrous liquid soap. Concentrations between 2.4 and 17.8 g/100 cm<sup>3</sup> aqueous solution.







## Refractive Index.—(Continued)

Soap	$R_C$	$R_D$	$R_F$	$R'_C$	$R'_D$	$R'_F$
NaC <sub>16</sub> .....		0.480			0.289	
NaC <sub>16</sub> .....	0.467	0.471	0.476	0.283	0.284	0.286
KC <sub>16</sub> .....		0.471			0.284	
NaC <sub>18</sub> .....		0.475			0.287	
NaC <sub>18</sub> .....	0.475	0.480	0.484	0.286	0.288	0.290

## Electrical Conductivity of Aqueous Solutions

The values given are  $\Lambda = 10^3 \kappa / N_v$  where  $\kappa$  is the specific conductance of the solution in mhos

## Na SOAPS AT 90°C

$N_w =$	1.5	1.0	0.75	0.5	0.2	0.1	0.05	0.01	Lit.
NaC <sub>9</sub> .....		106.9		(127.5)	150.44	166.42	196.0	199.8	(26)
NaC <sub>12</sub> .....	96.2	104.2		109.5	113.4	125.5	157.0	193.9	(70)
NaC <sub>14</sub> .....	84.76	94.93	97.57	99.15	95.23	96.51	110.4	191.7	(70)
NaC <sub>16</sub> .....	84.5*	83.6	85.8	87.4	79.4	75.5	76.4	101.7	(80)
NaC <sub>18</sub> .....	81.5	88.3		76.1	77.4	76.0	78.0	125.9	(14, 70)
NaC <sub>22</sub> .....				80.96	61.99	67.09	78.58	141.7	(26)

\* From (87).

NaC<sub>14</sub> (70)

$N_w$	$\text{NaCl}_{16} \text{ (g)}$					$\text{NaCl}_{16} \text{ (g)}$		
	80°	70°	60°	50°	40°C	°C	$N_v$	
							0.01	0.1
1.5	75.1	65.4	55.2	44.8		85	114.7	73.1
1.0	84.3	73.6	62.2	51.5		75	99.9	64.3
0.5	87.5	74.6	62.3	52.1		65	85.1	55.4
0.2	84.0	71.5	59.8	50.0	40.0	55	72.6	46.8
0.1	85.1	72.6	60.6	50.7	40.5	45	66.3	
0.05	97.3	83.1	69.4	58.0	46.5			
0.01	169.0	144.3	120.5	100.6	80.3			

NaC<sub>16</sub>SO<sub>3</sub> (112)

$N_v$	65°	60°	55°	50°	45°	40°C
0.0666	45	41.5	38.6	35.6	32.3	29.5
0.0333	46	42.1	39.1	35.5	32.6	29.4
0.01665	51.6	47.2	42.7	39.1	34.9	31.4

NaC<sub>18</sub> AT 25° (55)

$1/N_v$	5	10	30.25	60.50	121	242	484	968
$\Delta$	22.09	20.1	20.9	25.95	34.1	47.1	57.6	61.6

NaC<sub>18</sub> AT 18° (112)

$10^3 N_v$	66.70	33.35	16.67	8.34	4.17	2.08	1.04	0.52
$\Delta$	19.27	20.67	23.58	28.08	38.40	49.44	54.72	61.44

NaC<sub>18</sub> (IDENTICAL FOR SOL AND JELLY) (53)

°C	5.0	10.0	15.0	18.0	22.0	25.0
0.4 $N_w$	13.94	16.22	19.13	20.95	22.62	25.84
0.6 $N_w$	15.10	16.95	20.35	21.65	22.64	25.97

## Na SOAPS AT 18°

$N_w$	1.0	0.6	0.4	0.2	0.1	0.05	0.01	Lit.
C <sub>18</sub> .....		21.67	20.80	19.77	20.46	20.59	30.09	(77)
C <sub>18</sub> *.....	26	30.1	29.6	28.9	29.0	30.5	49.60	(66)
C <sub>18</sub> .....			29.6	28.70	29.13			(84)
C <sub>18</sub> OH†.....	27.7	32.1	34.0	35.8	37.8	40.7		(71)

\* At 24°C. † 1.5  $N_w$  23.1, and 24° (79); 1.0  $N_w$  35.5; 0.5  $N_w$  43.8.

## K SOAPS AT 90° (16)

$N_w =$	1.0	0.75	0.5	0.2	0.1	0.05	0.02	0.01
C <sub>6</sub> .....	149.5		177.7	201.2	216.5	227.7	(241.2)	245.9
C <sub>8</sub> *.....	148.7		168.5	191.0	205.2	219.2	(234.5)	239.5
C <sub>10</sub> .....	145.9		156.3	180.9	200.6	211.9	(227.0)	232.4
C <sub>12</sub> †.....	143.2	142.6	146.0	144.2	159.7	195.9	(223.5)	233.0
C <sub>12</sub> †.....	136.2	144	147	136.6	162	191		
C <sub>14</sub> .....	136.2		135.4	130.8	121.8	136.6	181.6	224.3
C <sub>14</sub> †.....	138	132	127	120	117	117		

## K SOAPS AT 90°.—(Continued)

$N_w =$	1.0	0.75	0.5	0.2	0.1	0.05	0.02	0.01
C <sub>16</sub> .....	124.2	127.9	127.0	111.0	107.0	110.8	133.2	171.6
C <sub>18</sub> .....	113.4	112.6	113.9	100.0	96.0	101.7	124.9	147.7
C <sub>18</sub> †.....			126	117	114.5	113		

\* 107.3 at 3.063  $N_w$ . † 123.5 at 2.028  $N_w$ . ‡ Concentration  $N_v$  (51).

## K SOAPS (51)

°C	$N_v$ at 90° =	0.05	0.1	0.2	0.375	0.4	0.6	0.8	1.0
60	C <sub>12</sub> .....	123.6	105	93.9	102.8	103	106	104.5	99.6
	C <sub>14</sub> .....	77.1*	77.4	77.6	88.5	90.1	95	92.9	89
	C <sub>18</sub> .....	80.3†	81.5	77.0	86.3	87.5	88.6		
45	C <sub>12</sub> .....	95.4	83.0	74.3	82.3	81.8	88.5	83.6	79.5
	C <sub>14</sub> .....	57.9*	58.7	60.9	69.5	70.7	75	74.2	72.0
	C <sub>18</sub> .....	61.0†	60.7	60.4	67.7	68.8	70.7		
30	C <sub>14</sub> .....	47.7*	47.2	46.2	51.6	52.5	55.9	56.0	54.9
20	C <sub>12</sub> .....	59.1	50.0	44.8	50.6	50.8	53.7	52.0	52.1
	C <sub>14</sub> .....	35.7*	39.5	33.0	35.5	36.0	38.4	41.4	45
	C <sub>18</sub> .....	37.1†	36.9	35.5	39.9	40.5	42.6		

\*  $N_v = 0.054$ . †  $N_v = 0.0518$ .KC<sub>16</sub>; EFFECT OF TIME (3); see further (53)

°C	85	75	65	55	45	35	25
0.01 $N_v$ .....	136.4*	118.8	100.5	86.7	79.6	→ 87.6	→ 92.8†
	140.8†						
0.1 $N_v$ .....	88.9	78.7	68.4	58.8	49.1	41.0	35.8

\* 10 min. † 60 min. ‡ All at 45°, 0 min, 20 min and 24 hr resp.

## K SOAPS AT 18°

$N_w$	2.0	1.0	0.75	0.5	0.2	0.1	0.05	0.01	Lit.
C <sub>8</sub> .....	42.24	48.60	49.75	53.00	63.05	69.50			(77)
C <sub>12</sub> .....	43.14	47.09	47.21	45.44	41.77	44.03	54.89	75.4	(77)
C <sub>18</sub> .....				37.0	33.30	29.74	29.57	51.95	(77)
Elaidate.			38.01	35.83	34.04	35.05	47.35		(90)

C<sub>16</sub>SO<sub>3</sub>H AT 90° (100); cf. (112)

$N_w$	0.75	0.5	0.2	0.1	0.05	0.02	0.01
$\Delta$ .....	237	232.0	203.9	188.1	185.5	195.0	208.0

K AND NH<sub>4</sub> SALTS OF FATTY ACIDS FROM PALM-KERNEL OIL (28, 51)

## MOLTEN K AND Na SOAPS (9)

## MIXTURES: SOLUTIONS OF SOAPS WITH ADDITIONS OF SALTS, ACIDS AND BASES (3, 24, 27, 28, 51, 70, 89, 109)

## Gold Numbers and Detergent Action, v. (37, 38, 50, 57, 74, 104, 105, 106, 108, 114, 117, 119, 120, 121, 122)

## Hydration

 $H_2O$  = moles H<sub>2</sub>O per mole soap

Negative sorption from lyes which salt out curd fibers from aqueous solutions of soap, yield the following values expressed as the retention of the solvent assuming that none of the salts are sorbed. The conditions and methods of experiment are described in the reference cited. For negative sorption by NaC<sub>16</sub> from salt mixtures, v. (81).

$t, ^\circ\text{C}$	Soap	Orig. $N_w$	Salt	$N_w$	$H_2O$	Lit.
90	NaC <sub>18</sub> .....	0.5	NaOH	1.5	4.3	(88)
90	NaC <sub>16</sub> .....	1.0	NaOH	3.0	3.4	(88)
		1.0	NaOH	2.0	5.2	
		0.5	NaOH	1.5	6.5	
		1.0	NaOH	0.5	4.4	
			NaCl	2.0		



### Hydration.—(Continued)

$t, ^\circ\text{C}$	Soap	Orig. $N_w$	Salt	$N_w$	$H_2O$	Lit.
17-25	$\text{NaC}_{16}$ .....	1.0	Glycerol	0.6	4.3	(6)
		0.25	Glycerol	0.6	10	
90	$\text{NaC}_{12}$ .....	1.0	$\text{NaCl}$	Satd.	1.8	(86)
12-18	$\text{KC}_{12}$ .....	1.1	$\text{KCl}$	0.6	11.8	(9)
20	$\text{KC}_{12}$ .....	1.1	$\text{KCl}$	0.9	11.3	(64)
		1.6	$\text{KCl}$	0.8	10.1	
		2.6	$\text{KCl}$	0.67	9.4	
20	$\text{KC}_{12}$ .....	1.0	$\text{KCl}$	1.0	11.0	(23)
		1.5	$\text{KCl}$	0.86	10.8	
		2.9	$\text{KCl}$	0.65	8.6	
		1.0	$\text{KCl}$	0.1	24	
12-18	$\text{NaC}_{12}$ .....	0.25	$\text{NaCl}$	0.1	9.2	(76)

Hydration of soap in solutions of 1.0*N*<sub>w</sub> KC<sub>12</sub> containing known amounts of KCl at 18° by comparison of conductivity, migration, and vapor pressure (109).

KCl added ( $N_w$ )	0.5	0.7	1.0	1.5	2.0	2.5	3.0	3.5
$H_2O$	11 ( $\pm 1.1$ )	12.2	12.8	10	9.6	5.2	6.3	6.9

For vapor pressures during hydration and dehydration of solid  $\text{NaC}_{18}$ , *v.* (50).

### Hydrolysis

The values given are % hydrolysis according to the equation:

$$\% \text{ hydrolysis} = \frac{(N_w \text{ of OH}^-) \times 100}{\text{Total } N_w \text{ of soap}}$$

1. Hydrolysis by hydrogen electrode, neglecting diffusion potential (results too high in concentrated soaps) (80).

Soap.....	$t, ^\circ\text{C}$	$N_w = 1.0$	0.75	0.5	0.2	0.1	0.05	0.01	0.001
NaC <sub>18</sub> .....	90°	0.2	0.27	0.38	0.55	1.3	5.5	6.6	
KC <sub>18</sub> .....	90°	0.08	0.27	0.6	0.65	1.3	5.0	6.8	
NaC <sub>17</sub> .....	25°	(88)				0.1(?)		0.6(?)	4(?)

### Hydrolysis.—(Continued)

0.5N<sub>10</sub> SOAP AT 90°

Soap.....	KC <sub>16</sub>	KC <sub>14</sub>	KC <sub>12</sub>	KC <sub>10</sub>	KC <sub>8</sub>
% Hydrolysis.....	0.64	0.54	0.36	0.076	0.072

2. Hydrolysis by catalysis of nitrosotriacetoneamine; values of  $10^5 N_v$  of  $\text{OH}^-$ . Results in concentrated soap probably low owing to sorption of amine.

NaC <sub>16</sub> (65)	$N_w =$ .....	0.042	0.5	0.8	1.0	0.46	0.1		
	$t, ^\circ\text{C}.$ .....	90	90	90	90	70	70		
	$10^5 N_v \text{OH}^-$ .....	91	20	25	27	44	56		
KC <sub>16</sub> (65)	$N_w$ .....	90°	0.019	0.042	0.1	0.3	0.85		
	$10^5 N_v \text{OH}^-$ ...		76	93	93	58	11		
	$N_w$ .....	70°	0.05	0.1	0.85	40°	0.051	30°	0.05
	$10^5 N_v \text{OH}^-$ ...		55	61	6		39		97
NaC <sub>18</sub> , 90° (5)	$N_w$ .....		0.002	0.01	0.02	0.05	0.1		
	$10^5 N_v \text{OH}^-$ .....		55	66	74	98	79		

Various Good Commercial Soaps at 90°; Values of  $10^6 N_v$  of  $\text{OH}^-$   
(5)

$x^* =$	1	0.5	0.1	$x^* =$	0.5
Coconut oil.....	31	21	5	Washer.....	77
Olive oil.....	73	60	18	Tallow rosin.....	79
Toilet soap.....	76	60	24	Coal tar.....	82
Cold process.....	108	80	30	Shaving.....	94

\* Grams soap in 100 cm<sup>3</sup> solution at room temperature.

3. Hydrolysis by indicator method. Comparison of the color given an indicator in a pure soap solution with that of standard buffer solutions. Buffers were Sørensen and Palitzsch's glycine/NaOH and borax/boric acid. Indicators were Alizarin yellow G for 0.003 to 0.0005*N*, OH<sup>-</sup>; phenolphthalein for 0.0008 to 0.0001*N*, OH<sup>-</sup>, and for extremely dilute soap, phenol red. The myristic acid used was impure. Indicator was added in amount to produce the maximum color (75).

Soap	$t, ^\circ\text{C}$	VALUES OF $N_w$ OF SOAP										
		0.5	0.2	0.1	0.05	0.02	0.01	0.005	0.002	0.001	0.0,5	0.0,1
NaC <sub>12</sub> .....	90	0.6	1.0	1.4	1.8	2.4	2.1	1.6				
	20	0.2	0.6	0.9	1.4	1.4	1.7	1.4				
KC <sub>12</sub> .....	90	0.7	1.2	1.6	2.2	1.6	2.4	Also 0.35 at $N_w = 0.86$				
	20	0.17	0.50	0.70	1.4	1.2	1.9	Also 0.12 at $N_w = 0.86$				
NaC <sub>14</sub> .....	90		0.56	1.11	2.2	3.85	4.3	Also 0.23 at $N_w = 0.4$				
KC <sub>14</sub> .....	90		0.56	1.1	1.6	1.75	2.9	Also 0.3 at $N_w = 0.4$				
KC <sub>16</sub> .....	90	0.20	(1.0)	1.6	3.1	4.8	6.7	9.7		12.4	19.1	
	20						14				51	
NaC <sub>16</sub> .....	90	0.2	(1.1)	1.6	1.6	4.1	7.0	8.0	15.5	15.8	18	
	20								35	27	68	
NaC <sub>18</sub> .....	90	0.2	0.5	0.9	3.0	(6.0)	12		35			
	20							13.2				
KC <sub>18</sub> .....	90		0.76	1.55	3.3	(8.6)	(15)	(20)	(50)	67	68	
	20										60	
NaC <sub>18</sub> <sup>-</sup> .....	90		0.41	0.85	2.0	5.0	8.5	(10.1)	(21)	24	16	
	20			0.24	1.6	2.7	4.5	6.3	16.1	24	28	
KC <sub>18</sub> <sup>-</sup> .....	90	(0.2)	0.7	1.5	2.9	5.9	6.9	9.2		18	16	
	20	(0.01)	0.08	0.2	1.4	3.8	2.0	5.9		23	28	
NaC <sub>22</sub> .....	90		3.4	6.8	13.6	32.5	27					
	20		Jelly			Viscous liq.		Clear				
			45 (Viscous liq.)					68 (milky liq.)				

$\text{NaC}_{10}$  and  $\text{KC}_{10}$  with excess of fatty acid, v. (75). Other determinations with various soaps and with added material, v. (50, 52, 53, 55, 57, 75, 76, 80, 112).



## LITERATURE

(For a key to the periodicals see end of volume)

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## DAS LITERATURVERZEICHNIS

In allen Literaturstellen, die in I. C. T. verzeichnet sind, ist der Name der Zeitschrift oder der Publikation mit Hilfe einer *Schlüsselnummer*, entsprechend der unten folgenden Liste, angegeben. Die Zahlen, welche diesen Schlüsselnummern bei einem Literaturzitat folgen, bedeuten der Reihe nach: (1) der Band, (2) die Seite und (3), die letzten zwei Zahlen des Jahrganges. So bedeutet z. B. 64V, 31: 253; 22, Verslag koninklijke Akademie van Wetenschappen te Amsterdam, Band 31, Seite 253, 1922. Seriennummern werden nicht angegeben. Der Schlüsselzahl wird ein *B* vorausgesetzt, wenn sie Bücher, oder eine andre nicht periodische Veröffentlichung bezeichnet. Die Bandnummer wird durch römische Ziffern angegeben. Es bedeutet z. B. also B10, IV: 191; 18, Doelter, Handbuch der Mineralchemie, Seite 191, des 4. Bandes, der Auflage des Jahres 1918. Die Schlüsselzahl *O* wird gebraucht, um anzuzeigen, dass es eine "private Mitteilung" ist.

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In tutte le indicazioni bibliografiche che si incontrano nelle "Tabelle Critiche Internazionali" il nome del giornale o della pubblicazione è espresso con un *numero chiave* riportato nell'elenco dato più oltre. I numeri che, nella citazione, vengono dopo il numero chiave sono disposti con l'ordine seguente: (1) il volume, (2) la pagina, e (3) le ultime due cifre del millesimo. Così 64V, 31: 253; 22, indica la Verslag koninklijke Akademie van Wetenschappen te Amsterdam, Vol. 31, pagina 253, 1922. I numeri di serie non vengono dati. Quando un numero chiave è preceduto dalla lettera *B* si riferisce a libri o ad altre pubblicazioni non periodiche, e il numero del volume viene allora scritto in cifre romane. Così B10, IV: 191; 18, indica Doelter, Handbuch der Mineralchemie, pagina 191 del IV° volume dell'edizione 1918. Il numero chiave *O* indica "Comunicazione privata da . . ."

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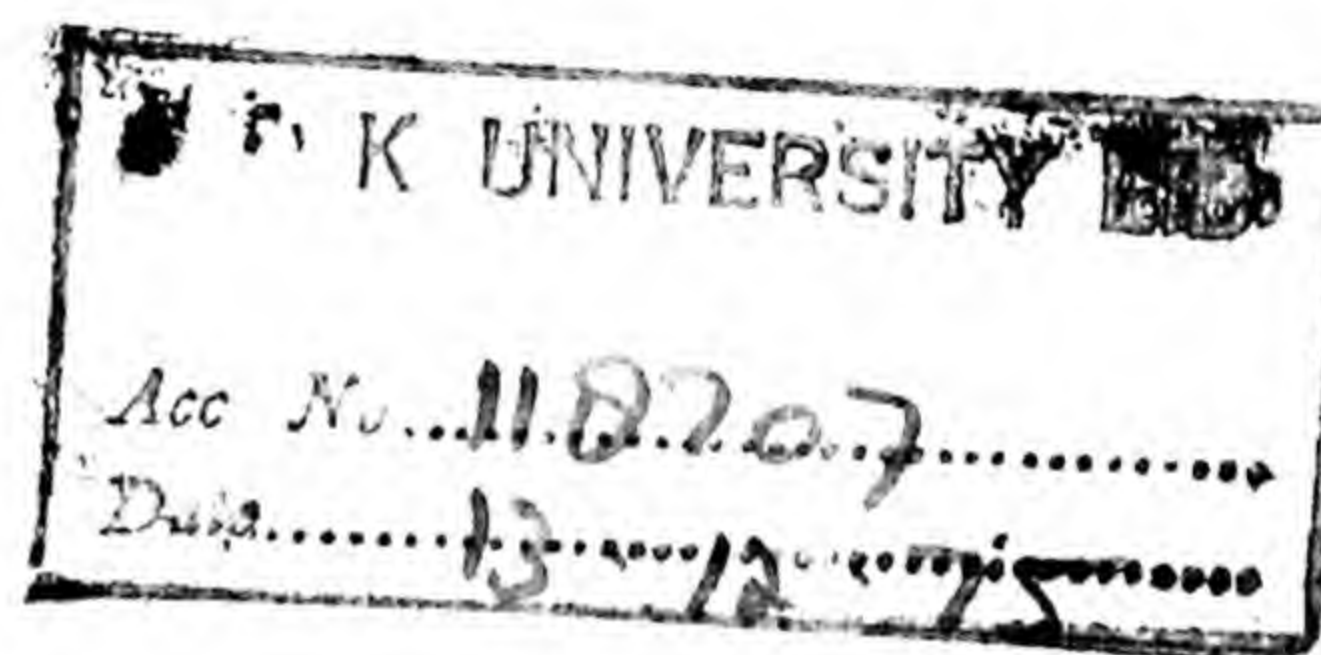
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# INTERNATIONAL CRITICAL TABLES

## INDEX

Volumes I to V Inclusive

**Explanation.**—For properties of natural and industrial materials of more or less indefinite chemical composition, look under the class of material. For properties of chemical substances and mixtures of definite composition, look under the property.  
Volume numbers are in bold-face.

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#### I. THE GASEOUS STATE\*

Property	Air†	Hg‡	H <sub>2</sub> O	SO <sub>2</sub>	NH <sub>3</sub>	CO <sub>2</sub>	CH <sub>3</sub> OH	C <sub>2</sub> H <sub>5</sub> OH	C <sub>6</sub> H <sub>6</sub>
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‡ Photographic efficiency of light from emission spectrum, 5: 299.

#### II. THE LIQUID (INCLUDING VITREOUS) STATE

	Air	Hg*	H <sub>2</sub> O	SO <sub>2</sub>	NH <sub>3</sub>	CO <sub>2</sub>	SiO <sub>2</sub> †	NaCl	KCl	CH <sub>3</sub> OH‡	C <sub>2</sub> H <sub>5</sub> OH‡	C <sub>6</sub> H <sub>6</sub>
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# XI. THE LIQUID (INCLUDING VITREOUS) STATE.—(Continued)

	Air	Hg*	H <sub>2</sub> O	SO <sub>2</sub>	NH <sub>3</sub>	CO <sub>2</sub>	SiO <sub>2</sub> †	NaCl	KCl	CH <sub>3</sub> OH‡	C <sub>2</sub> H <sub>5</sub> OH§	C <sub>6</sub> H <sub>6</sub>
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§ C<sub>2</sub>H<sub>5</sub>OH, Odor, 1: 360; Spray electricity, 1: 359.

|| C<sub>6</sub>H<sub>6</sub>, Odor, 1: 360.

# III. THE CRYSTALLINE STATE

	Hg	H <sub>2</sub> O	SO <sub>2</sub>	NH <sub>3</sub>	CO <sub>2</sub>	SiO <sub>2</sub> *	NaCl†	KCl†	CH <sub>3</sub> OH	C <sub>2</sub> H <sub>5</sub> OH	C <sub>6</sub> H <sub>6</sub>
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